Rainfall Interception by Midgrass, Shortgrass, and Live Oak Mottes

T.L. THUROW, W.H. BLACKBURN, S.D. WARREN, AND C.A. TAYLOR, JR.

Abstract

Interception, as a function of simulated rainfall intensity and duration, was determined for a midgrass [sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)] and a shortgrass [curleymesquite (*Hilaria belangeri* (Steud.) Nash)]. In addition, the redistribution of natural precipitation via plant interception was determined for live oak (*Quercus virginiana* Mill.) mottes. Interception storage capacity for sideoats grama and curleymesquite was 81 and 114% of dry weight, respectively. This difference was attributed to physical characteristics of the species and their respective growth forms. However, because sites dominated by sideoats grama had more standing biomass (3,640 kg ha^{-1}) than sites dominated by curleymesquite (1,490 kg ha^{-1}), it was estimated that a sideoats grama dominated site had an interception storage capacity of 1.8 mm compared to curleymesquite dominated site with an interception storage capacity of 1.0 mm. Based upon precipitation event size and distribution for the study site at the Texas Agricultural Experiment Station near Sonora, Texas, the estimated interception loss for curleymesquite dominated sites was 10.8% of annual precipitation, compared to 18.1% interception loss for sideoats grama dominated sites. Only 54% of the annual precipitation reached mineral soil beneath the oak mottes as throughfall or stemflow. The remainder of the precipitation was intercepted by the motte canopy or litter layer and evaporated. Due to the water concentrating effect of stemflow, soil near the base of trees received about 222% of annual precipitation. Soil at a distance greater than approximately 100 mm from a tree trunk received only 50.6% of annual rainfall. Individual tree canopy width, height and depth measurements were insignificant predictors of stemflow and throughfall. Interception, throughfall and stemflow, expressed as percent of storm precipitation, were well-defined curvilinear functions.

Key Words: standing crop, rainfall intensity, rainfall duration, throughfall, stemflow

Availability of water is one of the predominant factors influencing rangeland productivity. It has been demonstrated that plant interception can substantially influence the water budget of an area (Clark 1940, Kittredge 1948, Helvey and Patric 1965, Delfs 1967, Corbett and Crouse 1968, Douglass 1983, Hibbert 1983, and Seastedt 1985).

To date, grass interception research has been characterized by a diversity of techniques that includes simulating rainfall on grass clippings arranged in a wire basket (Beard 1956), sealing the soil surface with Neoprene and measuring the amount of runoff (Corbett and Crouse 1968), measuring the amount of water that reached a collection area below grasses that had been cut at the soil surface and placed on a screen over a funnel (Clark 1940), or the use of interceptometer pans (Clark 1940). Clark (1940) reported that interception losses by big bluestem *(Andropogon gerardi Vitman.)*, a tall grass 560 to 910 mm in height, ranged from 57 to 84% of simulated rainfall applied at intensities of 3 to 25 mm for a duration of 30 minutes. He likewise determined the interception losses by buffalograss [*Buchloe dactyloides* (Nutt. Engelm.], a shortgrass, to be 17 to 74% of simulated rainfall applied at intensities on 3 to 13 mm for a duration of 30 minutes. Haynes (1940) estimated interception loss by Kentucky bluegrass (*Poa pratensis* L.) to be 56% of annual precipitation. Beard (1956) estimated interception loss from a South African grassland composed primarily of *Themeda* spp. and *Cymbopogon* spp. to be about 13% of annual rainfall. Kittredge (1948) estimated net interception of a California grassland composed primarily of *Avena* spp., *Stipa* spp., *Lolium* spp. and *Bromus* spp. to be about 26% of annual precipitation. Few attempts have been made to express interception as a function of biomass or cover, even though these factors have been identified as major sources of potential variation (Clark 1940, Haynes 1940).

It has been documented that some tree species intercept a greater percent of annual precipitation than others (Kittredge 1948, Helvey and Patric 1965, Helvey 1971). Generally, coniferous and hardwood (with leaves) species' interception loss averages about 30 and 13%, while stemflow is approximately 3 and 5%, respectively of the annual precipitation. Canopy interception by shrubs has been documented by relatively few studies (Tromble 1983) with interception losses ranging from 4 to 50% depending upon canopy density and species. Shrub interception studies have been mostly restricted to California chaparral species (Hamilton and Rowe 1949) or juniper (Skau 1964, Young et al. 1984) whose interception losses averaged about 13 and 18%, respectively, of annual precipitation. Litter interception is largely determined by the amount of litter accumulated and its drying rate (Helvey and Patric 1965). Maximum water holding capacity of eastern forest litter, expressed as a percent by weight, has been reported to range from 215% (Helvey 1964) to 263% (Bernard 1963).

Watersheds where vegetation cover has been converted from shrub to grasses have yielded significantly greater amounts of water in areas receiving more than 457 mm of annual precipitation (Burgy and Pomeroy 1958, Corbett and Crouse 1968, Hibbert 1983). Increased runoff associated with conversion of shrub cover to grass cover has generally been attributed to lower water use by grasses when compared to shrubs. However, investigators have documented that interception can be an important loss in addition to transpiration losses (Thorud 1967, Rutter 1967, Nicolson et al. 1968, Waggoner et al. 1969 and Murphy and Knoerr 1975).

Sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] and curleymesquite [*Hilaria belangeri* (Steud.) Nash] are the dominant bunchgrass and shortgrass over much of the Edwards Plateau region of Texas. Live oak (*Quercus virginiana* Mill.) is a schlerophylous, evergreen, low-growing tree that covers 20 to 50% of the rangeland on the Edwards Plateau. The objectives of this study were: (1) to determine the relationship of interception storage to storm intensity and duration for bunch-type midgrass (sideoats grama) and sod-type shortgrass (curleymesquite) growth forms; and (2) to characterize interception by live oak motte canopy and litter, and the degree to which throughfall and stemflow redistribute the water reaching the soil. This project was part of a larger

Authors are presently range research scientist, Louis Berger International, P.O. Box 2954, Mogadishu, Somalia; hydrologist/research leader, USDA-Agricultural Research Service, Northwest Watershed Research Center, 270 South Orchard, Boise, Ida. 83705; watershed research scientist, USA-CERL, Environmental Division, P.O. Box 4005, Champaign, Ill. 61820; and superintendent of the Texas Agricultural Experiment Station at Sonora, Tex. 76950. Send reprint requests to the fourth author. At the time of research, the first and third authors were graduate research assistants and the second author was professor of Watershed Management, Department of Range Science, Texas A&M University.

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effort to determine the influence of vegetation manipulation on the water budget.

Study Area

Research was conducted at the Texas Agricultural Experiment Station, located 56 km south of Sonora at 632 m elevation, in Edwards and Sutton Counties, Texas (30° N; 100° W). The rolling stony hill topography that characterizes the station is typical of the Edwards Plateau. Annual median precipitation, 1918–1984, was 438 mm and ranged from 156 mm to 1,054 mm. The annual mean precipitation for the same period was 609 mm. Such a wide disparity between the mean and median annual precipitation is indicative of the annual variability caused by frequent droughts and occasional very wet years. Cool-season precipitation is generally the result of frontal storms, whereas warm-season precipitation occurs from brief, intense convective storms. The mean frost-free period is 240 days.

Currently, the region's vegetation is a mixture of grasses, forbs, and woody species. Woody plant distribution is often clustered, with dominant species being live oak, ashe juniper (*Juniperus ashei* Buchh.), and honey mesquite (*Prosopis glandulosa* Torr. var. glandulosa). The dominant midgrass is sideoats grama and the dominant shortgrass is curleymesquite. Oak mottes at the study site were characterized by a dense monospecific canopy with sparse undergrowth and heavy litter accumulation.

Methods

Midgrass and Shortgrass

During July, 1984, monospecific, 300 by 300-mm squares of sideoats grama and curleymesquite sod were excavated and placed into a square wire mesh container of the same size. The plants were actively growing, and the standing crop was typical of natural variation of the study site. The container held the soil and rooted portion of the grasses together and thus maintained the original configuration of the grasses. These grass sample units were taken to the laboratory where simulated rain was applied within minutes of collection. Moisture content of excavated grass sample units was determined by clipping adjacent representative samples of grass, weighing the samples, drying them at 60° C for 48 hours and reweighing them.

Water was applied to the grass sample using a drip-type rainfall simulator (Blackburn et al. 1974). Ten sample plots of each grass species for each rainfall intensity/duration combination were used. The following combinations of rainfall intensity and duration were used: intensity of 25 mm h^{-1} for a duration of 1, 2.5, 5, 7.5, 10, 15, and 20 minutes; intensity of 114 mm h^{-1} for a duration of 0.3, 0.6, 1, 2.5, 5, 7.5, and 10 minutes; and 5 minutes duration with the intensity of 25, 50, 90, 114, 150, and 175 mm h^{-1}. The rainfall intensity/duration combinations were selected to establish interception response curves and to determine the interception storage capacity of the grasses. At the conclusion of the simulated rainfall, the samples were carefully placed in a freezer (-46° C) that was adjacent to the rainfall simulator. Water intercepted by the grasses was frozen within 5 minutes. The frozen grasses were clipped at the soil surface while in the freezer, and then weighed. The grass sample was composed of live and dead standing crop. Detached litter lying on the soil surface was not included in the sample. The grass was then dried at 60° C and weighed again. The difference between frozen grass weight and dried grass weight represented the sum of the plant water content and intercepted water. Water intercepted by the grass standing crop (expressed as percent of grass dry weight) was calculated by subtracting the percent moisture content of the representative grass sample (estimated from the moisture content data collected from grass of the same species growing adjacent to the excavated grasses) from the percent plant water content and intercepted water retained by the grasses after simulated rainfall. An analysis of variance was conducted to determine species' differences in interception of simulated rainfall. Duncan's multiple comparison test was used to separate the means (Steel and Torrie 1980). Significance levels were determined at $p \leq .05$.

Bimonthly vegetation cover and standing crop data were collected over a 7-year period (1978–1984) on a pasture that was continuously grazed at a moderate rate (8.1 ha/AU/yr) (Thurow et al. 1986). These data provided mean standing crop estimates for curleymesquite and sideoats grama dominated sites. Meteorological data collected at the study site over a 10-year period (1974–1984) were used to develop a mean distribution of annual size and frequency of precipitation events. The interception functions developed with simulated rainfall were than applied to the natural vegetation and meteorological data to estimate the interception rainfall retained by curleymesquite and sideoats grama-dominated sites.

Live Oak Mottes

Data were collected from 4 live oak mottes which were representative of the size and shape of mottes on the study site. Twenty rainfall events were sampled over a period of 1 year. Storm size, duration, and intensity were determined from a recording and a standard nonrecording raingage located in a grass interspace approximately 15 m from the live oak mottes. Throughfall, stemflow, and litter interception were measured in each motte. Canopy interception loss was determined by subtracting throughfall and stemflow measurements from total precipitation. Water infiltration rate into motte soil was determined by Thurow et al. (1986) using a rainfall simulator.

Throughfall was determined by randomly placing 40 receptacles beneath the canopy of the oak mottes. The receptacles were 250 mm tall and had a diameter of 150 mm. Throughfall in each receptacle was measured volumetrically within 12 hours of each rainfall event. The percent foliar cover above each receptacle was measured by ocular estimate as an observer stood directly over the receptacle and peered upward through a cylinder 1,000 mm long and 150 mm in diameter. Absolute cover was measured by calculating the mean number of hits recorded when extending a telescoping rod through the canopy from 5 locations within each receptacle.

Stemflow was measured by fastening aluminum collars around 46 randomly selected live oak trees. The collars were affixed to the trunks with silicone sealant at a height of 600 mm. The collars funneled stemflow into storage bottles. Stemflow was measured volumetrically within 12 hours of each storm and expressed as a percent of precipitation. Trunk diameter at breast height (dbh), canopy circumference, canopy depth, and tree height were measured for each collared tree.

Litter accumulation was determined on 30, 0.5-m^2 plots randomly located within the oak mottes. Large branches and other bulky organic debris that would have distorted the litter estimate were excluded. For the purpose of this study, the term "litter" is defined as that part of the motte floor that lies above mineral soil, being composed of a layer of relatively unaltered organic litter, a layer of partly decomposed organic matter, and a humus layer that could be visually separated from the mineral soil. A drying rate curve similar to those expressed by Blow (1955) and Helvey (1964) was determined by collecting and weighing field samples of litter each day at noon for a period of 15 rain-free days following a storm of 55 mm which had saturated the litter layer. Thus, field capacity measured as water content (percent by weight) of litter 1 day after rain (Blow 1955) and minimum water content were determined. The maximum water holding capacity of the litter was determined by placing a preweighed sample of the litter profile into a 10,000-mm^2 tray with a 2-mm wire mesh bottom, weighing the tared sample, applying 80 mm of water by simulating rainfall at a rate of 10 mm hr^{-1}, and weighing the sample after drainage had ceased (approximately 30 minutes later). Rainfall amounts of 5, 10, 20, and 40 mm were also simulated. Ten samples for each simulated rainfall amount were collected. Rainfall was applied using a drip-type rainfall simulator (Blackburn et al. 1974). This method provided data needed to construct a curve of litter interception as percent of storm intensity.

All statistics were calculated using SAS Institute Inc. (1985) procedures. Regression analysis was used to determine the degree of association between variables. Analysis of variance techniques were conducted to determine if differences between oak mottes existed for throughfall, stemflow, or litter accumulation (Steel and Torrie 1980). Significance levels were determined at $p \leq .05$.

Results and Discussion

Midgrass and Shortgrass

Curlymesquite and sideoats grama represent 2 different grass growth forms. Curlymesquite is a stoloniferous species with flat blades (50–200 mm long and 1–2 mm wide) that are pilose (1–2 mm long). The slender stolons grow horizontally along the soil surface and are characterized by wiry internodes and pubescent nodes. In contrast, the sideoats grama at the study site is characterized by a bunch growth form that has flat to subinvolute blades (20–300 mm long and 2–4 mm wide) with scattered hairs only along the blade edges. During the 7-year period (1978–1984), curleymesquite dominated sites had a mean foliar cover of 56% and a mean standing crop of 1,490 kg ha^{-1}. Sites dominated by sideoats grama had a mean foliar cover of 62% and a mean standing crop of 3,640 kg ha^{-1}.

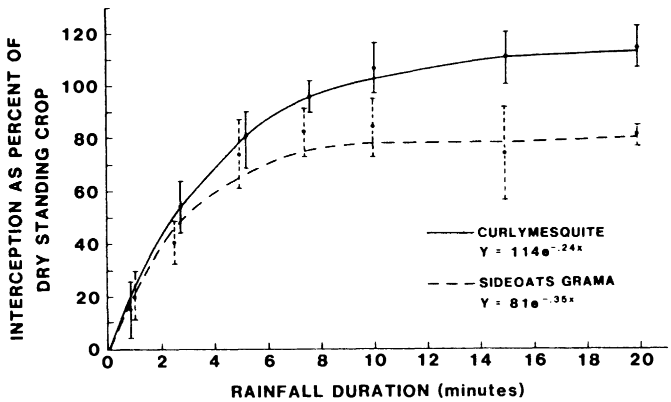

Fig. 1. *Interception as percent of dry standing crop across time for a rainfall intensity of 25 mm hr^{-1}. Vertical bars indicate confidence limits (p≤.05). Interception response curves denote predicted dependent variables from an intuitive model based on the exponential saturation growth function.*

The interception storage capacity of curlymesquite (114% of dry weight) was significantly greater ($p \leq .05$) than the interception storage capacity of sideoats grama (81% of dry weight) (Figs. 1–3).

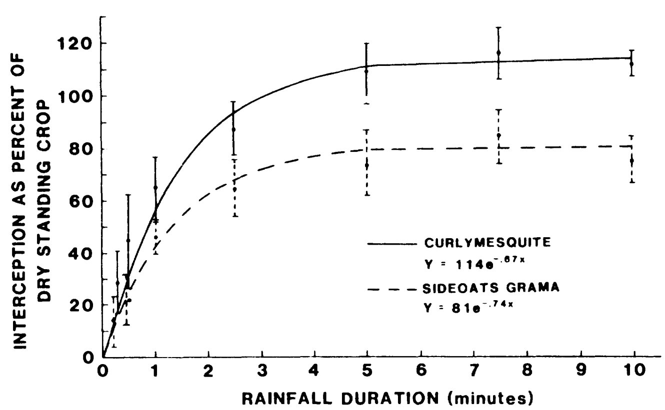

Fig. 2. *Interception as percent of dry standing crop across time for a rainfall intensity of 114 mm hr^{-1}. Vertical bars indicate confidence limits (p<.05). Interception response curves denote predicted dependent variables from an intuitive model based on the exponential saturation growth function.*

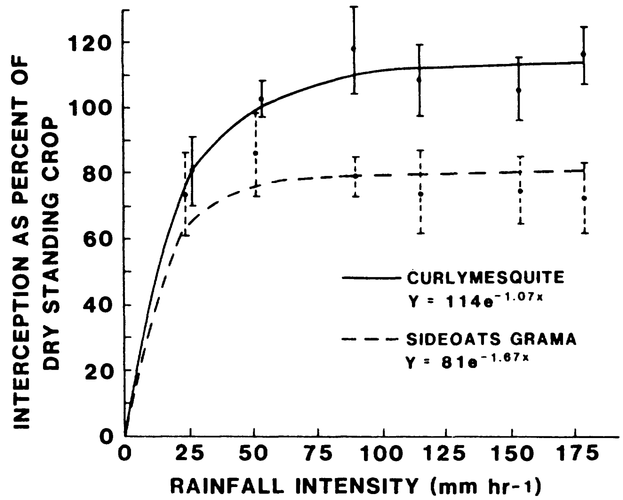

Fig. 3. *Inteception as percent of dry standing crop after a rainfall duration of 5 minutes. Vertical bars indicate confidence limits (p<.05). Interception response curves denote predicted dependent variables from an intuitive model based on the exponential saturation growth function.*

It is hypothesized that the pilose blades and the horizontal growth form of curlymesquite aided water retention, compared to the relatively vertical smooth blades of sideoats grama. The length of time needed to reach the storage capacity of the grasses varied with rainfall intensity. Interception storage capacity per unit dry weight was exceeded after 8 minutes for the 25 mm h^{-1} rainfall event (Fig. 1) and after 5 minutes for the 114 mm h^{-1} event (Fig. 2). Likewise, storage capacity was exceeded by storm intensity of 40 mm h^{-1} for 5 minutes (Fig. 3).

The greater potential for curlymesquite foliage to intercept water is offset by a lower standing crop production potential when compared with that of sideoats grama. Consequently, the interception storage capacity was significantly greater for sideoats grama-dominated sites (1.8 mm) than for curlymesquite-dominated sites (1.0 mm). These values are comparable with the estimated storage capacity of 1.1 mm for a mixture of fescue (*Festuca* spp.) and soft chess (*Bromus mollis* L.) (Burgy and Pomeroy 1958). Based on the 10-year mean storm size distribution of the study site, interception loss from curlymesquite-dominated sites would be 10.8% of annual precipitation compared to 18.1% loss from sideoats grama-dominated sites. Interception loss corresponds to the amount of grass standing crop and would thus be greatest during the growing season and lowest during the dormant season.

Live Oak Mottes

Most rainfall at the study site occurred as convective or frontal storms which were characteristically intense, short duration events. Analysis of data showed no significant differences for stemflow or throughfall attributable to duration or intensity of storm. Seasonal variability was not evident due to the evergreen nature of the live oak foliage. Thus, storm size was the principal determinant of stemflow and throughfall. In addition, there were no differences in stemflow, throughfall, or litter accumulation among the 4 mottes monitored in this study; therefore, data from the 4 mottes were pooled.

The mean foliar cover above the throughfall receptacles was 42% and ranged from 3 to 85% with a standard deviation of 25.3. Mean absolute cover was 124% and ranged from 5 to 400% with a standard deviation of 107.6. For small rainfall events, percent throughfall was approximately the inverse of percent foliar cover (Fig. 4), implying that most of the water striking foliage was held within the canopy. As storm size increased, percent throughfall increased due to drip loss from the canopy, and eventually became fairly

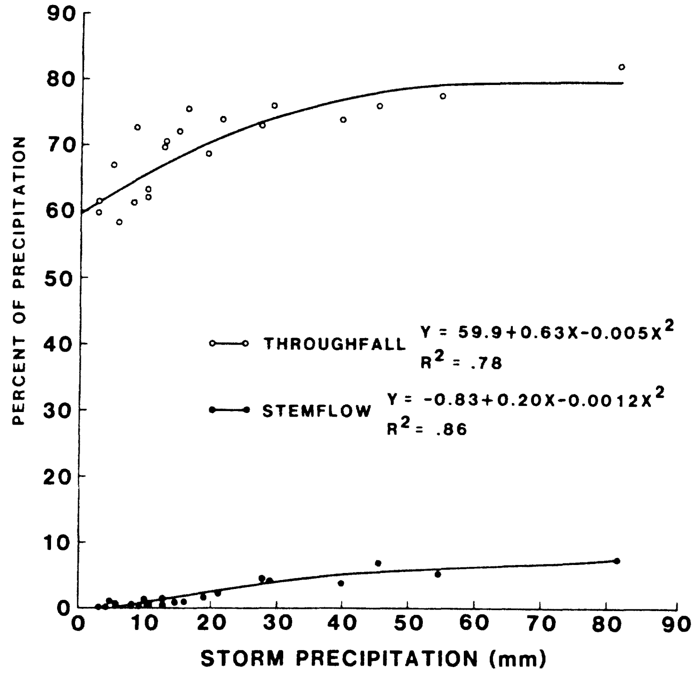

Fig. 4. *Percent of precipitation within oak mottes occurring as throughfall or stem flow as a function of storm size, Edwards Plateau, Texas.*

constant. Throughfall was poorly correlated with either the percent foliar (R^2 = .13) or percent absolute cover (R^2 = .18) above the throughfall receptacles indicating that other, unmeasured variables such as drip-points played an important role in determining throughfall.

In much of the early literature, throughfall was reported as a percentage of gross rainfall, a term that is of little value when storm size distribution is not presented. More recent studies use linear regression or curvelinear functions to illustrate the percent of gross rainfall that occurs as throughfall across a range of storm sizes. The curvelinear approach is more descriptive when comparing the relative importance of the various factors reflecting rainfall redistribution as a function of storm size. Based on a 10-year storm size distribution pattern, throughfall at this study site will account for approximately 73.3% of annual rainfall (Table 1). This value is

Table 1. Distribution of annual rainfall within oak mottes based on the 10-year average storm size distribution at the study site, Edwards Plateau, Texas.

	Water (mm)	Percent of Annual Rainfall
Annual precipitation	523	
Throughfall	373	71.3
Stemflow	17	3.3
Canopy interception	133	25.4
Litter interception	108	20.7
Water reaching mineral soil	282	53.9

slightly lower than average deciduous forest estimates of 80 to 85% (Kittredge 1948, Helvey and Patric 1965). The value is similar to the 70 to 75% determined for densely crowned open-grown trees (Lunt 1934, McMunn 1935, Fraser 1956). This is consistent with the typically dense canopy of live oaks. In addition, the rigid nature of the sclerophyllous leaves may facilitate water retention since they do not droop as do most other broad-leafed species when water is applied. The dense canopy and leathery leaves of live oak are typical of many other semiarid shrubby species implying that throughfall estimates developed on eastern deciduous hardwoods may not be representative of tree growth forms in semiarid regions.

Stemflow did not begin on most trees until gross precipitation exceeded 7 mm, but increased thereafter in a pattern similar to throughfall (Fig. 4). The mean dbh of the 46 collared trees was 90 mm (range 23–229 mm; SD–48 mm). The mean canopy diameter was 1.6 m (range 0.6–4.2 m; SD = 0.9 m). The mean tree height was 3.8 m (range 1.7–7.0 m; SD = 1.2 m). These values were poorly correlated with stemflow (R^2<0.2). The canopy volume and indices composed of various combinations of the measured variables also yielded low coefficients of determination (R^2<0.28). The greatest coefficient of determination was obtained by correlating stemflow with an index composed of canopy depth divided by canopy width (R^2 = .28). This index provides a general quantification of canopy shape (i.e., gradient ranging from tall and narrow to short and broad). This index to stemflow is intuitively sound since tall, narrow canopies have the potential to funnel more water down the trunk compared to broad, shallow canopies that have a horizontal branching structure with many potential drip points. Unmeasured variables such a branch angles, drip points along branches, bark roughness, lichen growth on bark, etc., are apparently important factors for predicting individual tree stemflow. Nevertheless, mean stemflow of the sample population was very predictable and the quadratic curve which fit the data accounted for a significant portion of the sample variation. The stemflow at the study site was 3.3% of annual rainfall (Table 1). This value is comparable to estimates summarized by Kittredge (1948) and Helvey and Patric (1965).

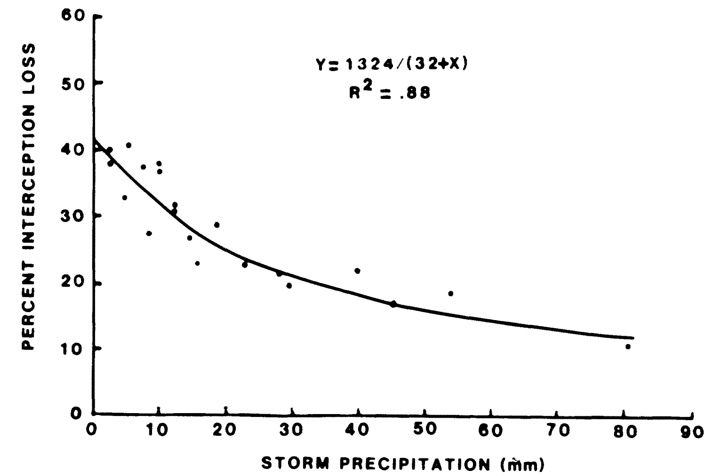

Fig. 5. *Interception loss by oak motte canopy as a function of storm precipitation, Edwards Plateau, Texas.*

Litter biomass under oak mottes averaged 41,300 kg ha^{-1}. This degree of accumulation is relatively high when compared to litter accumulation in most other regions of the country (Helvey and Patric 1965). The high accumulation of litter under live oaks in the study region may be attributable to the sclerophyllous oak leaves which are resistant to decomposition, the semiarid climate and low moisture availability which deter microbial decomposition, and the absence of fire. The 210% maximum interception by litter was similar to previously reported values of 225% (Blow 1955) and 215% (Helvey 1964). The minimum water content of litter was 17% which is similar to reported values of 20% (Blow 1955), 22% (Semago and Nash 1962) and lower than 40% reported by Helvey (1964).

The percent of precipitation intercepted by litter and oak canopy from storms of various sizes is illustrated in Figures 5 and 6. The percent precipitation reaching mineral soil based on a series of storm sizes is shown in Figure 7. On the average, 53.9% of the annual rainfall actually reaches the soil, 25.4% is lost by canopy interception and 20.7% by litter interception (Table 1). Distribution of water reaching the soil under the oak motte is variable. Stemflow concentrates water at the base of the trunks. Mean water

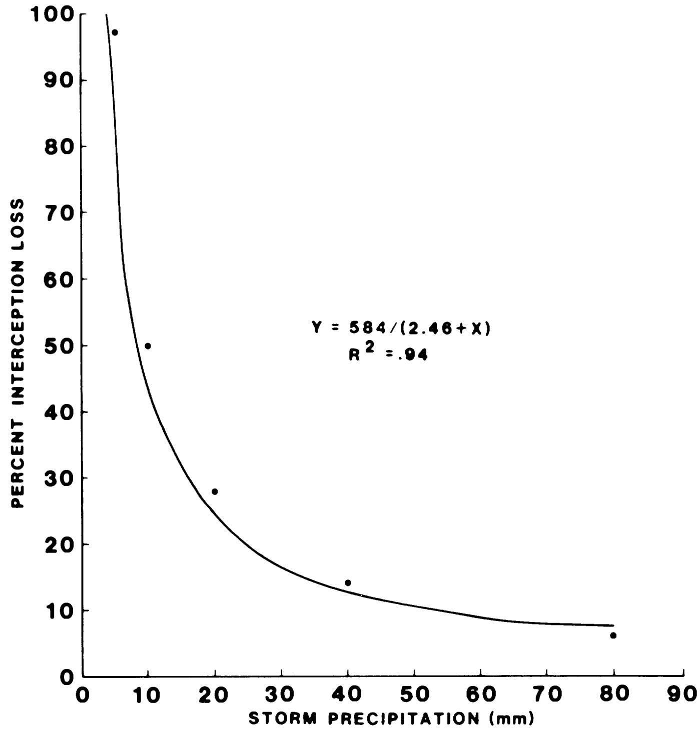

Fig. 6. *Interception loss by oak motte litter without a canopy as a function of storm precipitation, Edwards Plateau, Texas.*

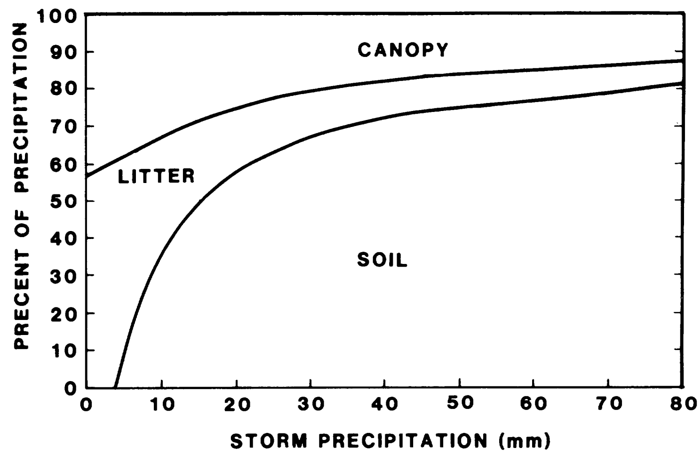

Fig. 7. *Precipitation within oak mottes reaching the mineral soil or evaporated as canopy or litter interception as a function of storm precipitation, Edwards Plateau, Texas.*

infiltration rate into oak motte soil was 199 mm hr^{-1} (Thurow et al. 1986). Based on a mean stemflow of 955 ml per storm event, a radius of about 100 mm around the trunk would be needed to fully accommodate infiltration of the stemflow. This means that a 100 mm radius of soil around the tree would receive approximately 222% of annual precipitation, whereas the soil under the canopy farther than 100 mm away from the trunk would receive only 53.9% of annual precipitation. This concentration of water at the base of the trees represents an effective water harvesting factor that could be an important mechanism of water and nutrient supply. Areas away from the tree trunks receive less rainfall, making it a drier environment for plant establishment and growth.

Interception data collected on live oak mottes (the dominant shrub species on the study site) confirm the intuitive expectation that shrub cover intercepts more than grasses. Live oak motte interception loss by the canopy was 25.4% of the annual precipitation. This implies that canopy interception losses from the shrub component may be 2.4 times greater than losses by the grass-dominated interspaces. Infiltration rate under oak mottes (199 mm hr^{-1}) is greater than for midgrass sites (162 mm hr^{-1}) or shortgrass sites (109 mm hr^{-1}) (Thurow et al. 1986). Shifts in the kind and amount of vegetation on the Edwards Plateau have the potential for greatly influencing the hydrologic water balance and, to a large extent, determining the amount of rainfall retained, lost, or yielded from a watershed.

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A Rapid Method for Assessing Rates of Soil Erosion from Rangeland: an Example from Botswana

NICK ABEL AND MICHAEL STOCKING

Abstract

The erosion of rangeland soils is a widespread problem in Africa. Yet, there are few methods for estimating its rate. Using data from 2 catchments in Botswana, a technique for estimating erosion and sediment yield is demonstrated. It involves low level photographic sampling of vegetation cover, kriging to interpolate percentage cover from sample points, and the application of a simplified soil loss estimation procedure called SLEMSA. This modelling approach gives gross soil loss and allows the estimation of sediment yield. It is easy and cheap to apply and gave results in line with field experience.

Key Words: Soil erosion, rangeland degradation, rapid rural appraisal, Botswana

Most semiarid regions report rangeland degradation because of heavy grazing (e.g., Pratt and Gwynne 1977; Penning de Vries and Djiteye 1982). Soil erosion is normally cited as a contributory process, but estimates of its rate on rangeland are scarce. This is not, we suggest, because such estimates are considered unimportant, but because technically feasible, cost-effective methods have yet to be developed for rangelands. In contrast, arable lands are relatively well served.

One reason for the lack of development of methods for rangeland and the poor compatability of existing methods for arable areas (e.g. Universal Soil Loss Equation, USLE: Wischmeier and Smith 1978) is the difficulty of estimating and interpreting the most influential variable in soil loss: vegetation cover. The USLE deals with vegetation cover primarily through its 'cropping management factor', C, which is empirically determined. Typically, many values of C are required for a single crop, each needing years of experimentation on erosion plots. Index values for C so derived have no inherently rational meaning other than as a comparative measure integrating a variety of unknown influences: extrapolation is impossible. Furthermore, the USLE is strictly valid only where the factor values for the equation have been experimentally determined, a situation that pertains only to cropland east of the Rocky Mountains in the United States. To extend these factor values to the different soils, climate, and land use of southern Africa is unwise without independent verification. However, the major control of erosion is through the protective cover of vegetation (Stocking and Elwell 1976), which, expressed as a percentage of the ground covered by vegetation, is a rationally explicable variable that can be used from prediction (Elwell and Stocking 1976).

On cropland, cover is fairly easily measured, usually by means of a quadrat sighting frame (Elwell and Gardner 1975). On rangeland, both the large areas involved and the spatial and temporal variability in vegetation cover preclude ground-based measurement and dictate the utilization of some form of remote sensing. Although much effort has gone into assessing ground cover by computer analysis of Landsat and NOAA imagery, initial enthusiasm (Tucker et al. 1983) has not been sustained by subsequent field tests. The accuracy of estimates of grass cover (and biomass) from satellite imagery is reduced by at least the following factors:

* techniques depend on the quantity of green material present, so that estimates are confined to the growing season (Curran 1983). Critically, the dry grass remaining at the end of the dry season for protection against the first rains cannot be assessed;
* it is not known whether sensors can distinguish between the canopies of the woody vegetation and the ground layer (Prince and Astle 1986, Prince and Tucker 1986);
* when vegetation cover is sparse, the background reflectance of the soil can swamp the reflectance of the vegetation, preventing accurate estimation of cover (Curran 1983);
* spatial variation in soils (Richardson and Wiegand 1977) and topography (Curran 1983) can further impair the accuracy of cover estimates;

Authors are respectively rangeland ecologist and soil scientist with the Overseas Development Group, School of Development Studies, University of East Anglia, Norwich NR4 7TJ, United Kingdom.

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