

Rainfall Interception by Annual Grass and Chaparral . . . *losses compared*



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P.O. Box 245, Berkeley, California 94701

Corbett, Edward S., and Crouse, Robert P.

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Edward S. Corbett and Robert P. Crouse

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The Authors

were formerly on the staff of the Station's San Dimas Experimental Forest, near Glendora, Calif., where they studied problems in flood and sediment reduction in brushlands. **EDWARD S. CORBETT**, a hydrologist, is now responsible for research on municipal watershed management at the Northeastern Forest Experiment Station, Upper Darby, Pa. He earned a B.S. degree (1958) in forestry at the University of Connecticut, and an M.S. degree (1960) in watershed management at the New York State University College of Forestry. **ROBERT P. CROUSE** is now principal resource analyst with the Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colo., and stationed at Tucson, Ariz. A 1950 graduate of Amherst College, he holds an M.F. degree in forest management from Yale University (1958).

Interception is the first hydrologic process that redistributes precipitation near the ground. Hamilton and Rowe (1949) defined it as the portion of precipitation that is returned to the atmosphere through evaporation from plant surfaces or that is absorbed by the plant. Interception then, is the difference between the precipitation falling over an area and the part that reaches the soil.

Information on rainfall interception by several brush types of central and southern California is available from earlier studies (Rowe 1948; Hamilton and Rowe 1949). But little information is available on interception loss from native or seeded grass covers and from grass litter (*fig. 1*).

Much of the foothill and mountain brushlands of southern California serve primarily as watersheds. Chaparral vegetation covers some 8.5 million acres of the watersheds in the State (Wieslander and Gleason 1954). Chaparral uses large quantities of water, is a great fire hazard, and provides little forage for livestock. Through the years proposals have been made that these brushlands be converted to grass. According to such proposals, grass would be less hazardous than brush, and is a more useful vegetative cover.

Before any large-scale conversion can be undertaken, it is necessary to know the probable effects of any vegetative changes on water yield and on soil erosion. Several studies on the effects of brush conversion on soil moisture and streamflow have



Figure 1.—Annual grass, as it reaches full development in spring, can hold a large amount of rain in storage.

been made recently. Rowe and Reimann (1961) reported the relative use of soil moisture by brush, grass, and grass-forb vegetation. The way vegetative changes on chaparral-covered watersheds affect surface runoff, streamflow, and erosion has been described by Rowe (1948, 1963), Rowe and Colman (1951), Pillsbury *et al.* (1962), and Corbett and Rice (1966).

This paper reports a study of rainfall interception loss from annual grass and grass litter (*Bromus mollis*) under natural conditions on the San Dimas Experimental Forest, in southern California. It describes relationships among growth stage of grass, storm size, and interception loss during three rainy seasons. The study was supported in part by the California Division of Forestry.

Interception Loss Defined

Some investigators believe that interception loss, as defined by Hamilton and Rowe (1949), is not a real loss to the plant-soil-water system. Instead, they propose two terms: “*gross interception loss*” to represent interception loss in that definition; and “*net interception loss*” to represent the part of the

precipitation retained on vegetative surfaces and evaporated that does not affect a plant's water use. Studies by Burgy and Pomeroy (1958), Rakhmanov (1958), and McMillan and Burgy (1960) suggested that intercepted water causes a compensating reduction in transpiration. Burgy and Pomeroy

(1958) and McMillan and Burgy (1960) applied artificial rainfall to the foliage of grasses under laboratory and field conditions. They found little or no net loss of water from the entire plant-soil-water system.

Goodell (1963) has questioned how large the net interception loss might be, considering these factors: (a) Transpiratory regulation by plants under the stress of limited water availability; (b) probability that the energy available for evapotranspiration from wet leaves is greater than that from dry leaves, and (c) the possibility that under winter conditions in cold climates, transpiration is limited more by the availability of water than of energy, and that interception increases the quantity of water favorably exposed to the energy supply. Furthermore, Rutter (1959, 1964, 1967) has shown that the rate of evaporation of water intercepted by foliage of Scotch pine (*Pinus sylvestris*) is many times greater than the rate of transpiration—indicating a differential net loss. A similar conclusion for other species is alluded to by Patric (1966), Helvey (1967), and Leyton *et al.* (1967). And Thorud (1967) found that 91 percent of water artificially applied to the foliage of potted 6- to 7-year-old ponderosa pine (*Pinus ponderosa* Laws.) was a net loss to soil moisture supplies. The reduction in transpiration as a percent of applied water varied from 4 to 14 and appeared to be related to weather conditions. This finding indicates that to

obtain *realistic* measurements of net interception losses, experiments should be conducted under actual storm conditions.

Interception loss on dead (non-transpiring) grass stubble and grass litter would be a net loss (Burgy and Pomeroy 1958; McMillan and Burgy 1960). But there may be a substantial reduction in soil evaporation owing to the insulation of a continuous litter layer (Blow 1955; Rowe 1955). On California's foothill ranges, Bentley and Talbot (1951) found that seeds of annual plants start to germinate after the first rains of ½ to 1 inch, which usually occur in October or November. Ordinarily most of the plants mature and dry in May. Thus annual grass vegetation is transpiring from late fall until early spring. During the rest of the year the foliage is dead.

The problem of assessing the magnitude of net interception loss is complicated by several factors. These factors include (a) the amount of living and dead plant surfaces; and (b) periods of minimum and maximum transpirational use as affected by season of year, time of day, climatic conditions, and soil moisture conditions. An assessment of the problem is beyond the scope of this paper. But Kohler (1958) points out that water intercepted by the vegetative cover is a net loss to surface precipitation and accordingly, can affect the surface runoff, soil moisture, and ground water phases of the hydrologic-cycle.

Magnitude of Grass Interception Loss

Early investigators of rainfall interception by grass include Musgrave (1938), who found that blue grass (*Poa spp.*) intercepted 17 percent of the rainfall during the month before harvest. But he did not account for stemflow (rainfall that reaches the ground by running down the plant stems) from the plants.

Clark (1940) placed narrow rectangular catch pans on the ground beneath a grass-forb cover in Nebraska. Where necessary he cut the plants and supported them in the pans by wires. Thus he recorded stemflow as part of throughfall (rainfall which reaches the ground through interplant spaces and as drip from leaves and stems) for some plants but not for others. Clark believed stemflow to be a minor factor in the redistribution of rainfall. The percent of interception loss varied with the amount of rainfall, density of foliage, and weather condi-

tions. Interception percentages were generally quite high, but the amount of rainfall, artificial and natural, was usually low. For big bluestem (*Andropogon furcatus*) 22 to 36 inches in height; interception loss ranged from 84 percent to 47 percent as amount of applied water spray varied from 1/8 inch to 1 inch. Under conditions of natural rainfall, a stand of fully developed big bluestem had interception losses ranging from 97 percent from a light shower of 0.06 inch to 63 percent for a heavy rain and subsequent showers totaling 1.20 inches. Interception losses for shorter growing grasses were less. When 1 inch of rainfall was applied in 1 hour the interception value of stink grass (*Eragrostis cilianensis*) was 18 percent and that of buffalo grass (*Buchloe dactyloides*) was 26 percent.

In measuring stemflow separately for several field crops Haynes (1940) used catch pans similar

to those in the Clark study. He had difficulty in getting an accurate measure of stemflow under grass crops however, and did not report its value. Over two growing seasons, he found that interception (excluding stemflow) in a stand of bluegrass, including the previous year's accumulation of litter, was 56 percent of the 41.64 inches total rainfall. Both Clark (1940) and Haynes (1940) cited the problems caused by growth changes in the vegetative cover and the effects on interception, but did not quantitatively evaluate these changes.

Kittredge (1948) found that grass species of

Avena, *Stipa*, *Lolium*, and *Bromus*, allowed to grow up over a trough gage 10 feet long and 4 inches wide, intercepted 25.9 percent of the 32.52 inches of seasonal rainfall. This value was not corrected for stemflow.

In contrast to Clark, Beard (1962), found that stemflow from grass made up a considerable portion of the rainfall reaching the soil. It ranged from 35 to 45 percent of the total rainfall during the sampling period. Interception loss from the grass (primarily *Themeda* and *Cymbopogon*) was about 13 percent of the total rainfall.

Study Methods

The San Dimas Experimental Forest, near Glendora, Calif., has a Mediterranean climate—hot, dry summers and mild rainy winters. Nearly all of the annual precipitation falls from November through April. Annual precipitation has ranged from 10 to 48 inches, and averages about 26 inches. About half the annual precipitation falls in storms 3 inches and larger. Records for 32 years show that mean monthly temperatures ranged between 47.3°F. in January and 72.6°F. in July and August. The average annual evaporation (U.S. Weather Bureau pan) was 63.1 inches over a 30-year period.

Measuring Interception Loss

A ½-acre study area was established on a 35-percent slope that had previously been converted from brush to grass. Hamilton and Rowe (1949) had used this same area to carry out their test on rainfall interception by chaparral. Sample sites on a 1/20-acre plot were burned to remove the old grass cover, litter, and undesirable seed. The sites were then seeded to Blando brome (*Bromus mollis*), a species commonly used in range and watershed conversion work and in reseeding brush burns. To hasten the establishment of a grass stand suitable for interception measurements, the sites were irrigated in fall after sowing.

After the grass cover became established, we drove 10-inch diameter metal collars into the soil so that about 1 inch of the collar remained above the soil surface. When the grass height reached 2 inches we sealed the soil surface within the collar. First, we sifted a layer of fine sand onto the soil to provide a uniform, sloping surface for drainage. Then we moistened the sand with water and ap-

plied two coatings of a neoprene latex emulsion (fig. 2). The tight, smooth, and durable seal obtained was non-toxic and did not affect the normal growth of the grass.

A drain in the side of each collar carried combined throughfall and stemflow to a collection can. Tipping bucket mechanisms were connected to five of the sites to measure the rate of combined



Figure 2.—Demonstration of technique used to apply neoprene sealer to soil surface inside metal collar.



Figure 3.—*Instrumentation used in the study shown by cutting away the grass at the end of a field season. A drain tube carried combined throughfall and stem-flow to the collector. A tipping bucket mechanism was used to measure rate of flow.*

throughfall and stemflow (*fig. 3*). Twenty collars were installed the first year of the study and 40 the second and third field seasons.

Gross precipitation was determined from four rain gages placed in the corners of the study area and from two ground level gages near the center of the area. Three of the corner gages were 8-inch standard gages. The fourth was a tipping bucket intensity gage. During a portion of the study a weighing recording gage was also used.

Grass interception loss was calculated as the difference between precipitation measured above the canopy and the equivalent inches of combined throughfall and stemflow. The amount of water retained on the equipment was taken into consideration in the calculations. The combined throughfall-stemflow measurements were made after any 24-hour, non-rain period. If the sky cleared after a rainy period, however, the measurements were made as soon as the water held in storage had completely evaporated.

One fall, several sample sites were used to measure interception loss from standing dead grass and the plant residue lying within the ring.

A 1-inch deep black pan evaporimeter, equipped with an overflow, was installed to obtain an index of evaporative potential during breaks in storms. This device could record losses to the nearest .001 inch. Wind speed, air temperature, and relative humidity were also continuously recorded.

Measuring the Grass Stand

Measuring the changes in grass growth throughout the growing season is essential to determine

how grass size is related to amount of interception loss. The quantity of grass at each site was measured three or four times during each growing season by the point method of range analysis with a modified point-quadrat frame (Levy and Madden 1933). This frame permitted a sharpened pin to be lowered vertically into the grass on a 25-point grid (*fig. 4*). The height (in inches) of the first hit of each pinpoint on grass foliage was used to determine the average height of the grass (Heady 1957). This measurement represents the height at which a raindrop might first be intercepted. The point quadrat was also used to determine the percent of ground cover (recorded as a decimal percent), and the average number of hits made by the pin as it was lowered through the grass to the ground. The average number of hits was used to estimate the number of layers of vegetation available to store intercepted rain. This value will be referred to as the storage area index (SAI). The grass measurements as well as other work on the sample sites were made from a portable platform to avoid trampling the grass.

Calculating Storage Capacity

The ability of grass to store precipitation against the force of gravity is one of the prime factors affecting interception loss. To investigate the effects of species and growth stage on interception capacity, we grew Blando brome, annual ryegrass (*Lolium multiflorum*), and tall wheatgrass (*Agropyron elongatum*) in 2.25-square-foot flats in a greenhouse. The flats were filled with a light-weight artificial soil (a mixture of perlite and vermiculite),



Figure 4.—A modified point-quadrat frame was used for measuring the average height of grass at the sample site and the percent of ground cover. It was also used to estimate the number of layers of vegetation available to store intercepted precipitation.

and the grass was watered with a nutrient solution. The soil surface was sealed with the neoprene latex emulsion. A drain carried off the throughfall and

stemflow. The grass in flats was measured at regular intervals in the same manner as grass in the field sites.

The flats—or portable "plots"—were easily moved into a spray booth where the rate of delivery and spray pattern of artificial rain could be controlled. The spray booth was placed in a tunnel where temperature and relative humidity were held constant. Interception storage tests were made at regular intervals throughout the growth cycle of the grass. A ½-inch light rain was applied—more than needed to satisfy the storage capacity of the grass. Storage capacity was calculated as the difference between the applied rainfall and the collected throughfall and stemflow—corrected for water retention on latex and drain surfaces.

Measuring Litter Interception Loss

In this study, grass litter was defined as the dead plant residue, recognizable as to origin, resting above decayed organic matter or mineral soil. Litter interception was measured in 10 20-inch diameter pans equipped with drains and collector cans. The pans were placed at ground level. Samples representative of maximum and minimum amounts of grass litter found in the study area were placed in the pans with as little disturbance to natural arrangement as possible. Decayed organic matter above mineral soil was not included. Measurement techniques of rainfall and throughfall were similar to those for the grass cover. In addition, the pans were weighed periodically before and after each storm to determine the moisture condition of the litter and its drying rates.

Results

Interception Storage Capacity of Grass

Storage area index (SAI) and the average height (in inches) times percent cover (HxC) index were evaluated as measures of interception storage capacity of grass. SAI showed a high variability between observers on the same sampling sites. HxC proved to be a better measure of the storage capacity and was used throughout this analysis. The HxC—storage capacity relationship was evaluated on plots having a relatively high percent cover.

HxC values were converted to storage capacity units by dividing by 100 so their magnitudes would be similar for comparison. The HxC values were found to be an adequate index of grass storage capacity, i.e., HxC of 2 divided by 100, equals 0.02 inch of storage capacity. The interception storage capacity increased rapidly as the grass increased in size—ranging from 0.01 inch to 0.20 inch during the growth cycle for the samples tested in the greenhouse study. The three species tested showed little difference in interception storage capacity (fig. 5).

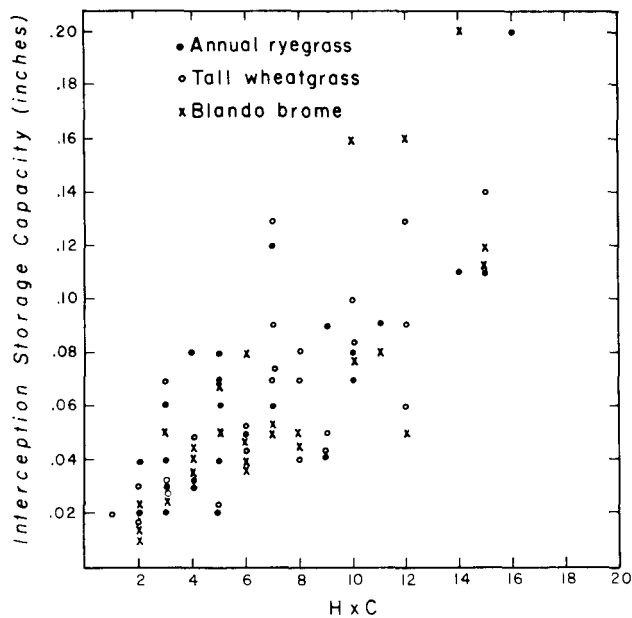


Figure 5.—Relationship between grass interception storage capacity and HxC index (average height, in inches, times percent cover), San Dimas Experimental Forest, California.

Interception Loss from Grass

During three field seasons only 25 storms totaling 9.80 inches of precipitation were sampled for grass interception measurements. The largest storm was 2.74 inches. Precipitation in this period was well below normal. And we had the difficulty of establishing a grass stand early enough in the win-

ter to measure interception from the early winter storms. The difficulties of predicting interception loss from the variables measured at the field sites have been summarized by Crouse *et al.* (1966).

To illustrate the relationships between interception loss and stage of grass growth, we developed curves of interception loss as a percent of rainfall for three different stages of grass growth, as characterized by the HxC measurements (*fig. 6*). Individual sample plots were grouped by HxC intervals of 1.0 to 4.9, 5.0 to 11.9, and 12.0 and greater. The largest HxC measurement made during the field study on an individual plot was 17.8. The average height of the grass stand was generally close to the HxC measurements because percent cover was always relatively high. Interception loss from mature chaparral (Hamilton and Rowe 1949) was included for a comparison with the grass interception results.

Interception loss increased as the grass stand developed throughout the growing season. Interception loss from storms 0.30 inch and less was high, and the rate of interception loss from storms greater than 1.5 inches was fairly constant (*fig. 6*). Grass interception loss for storms greater than 1.6 inches is based on only two storms. No large storms were sampled when the grass was in its very early stages of development.

Annual grasses start growth with the first rains of $\frac{1}{2}$ to 1 inch, usually in October or early November. However, growth may be limited by low temperatures, deficient precipitation, or both during the

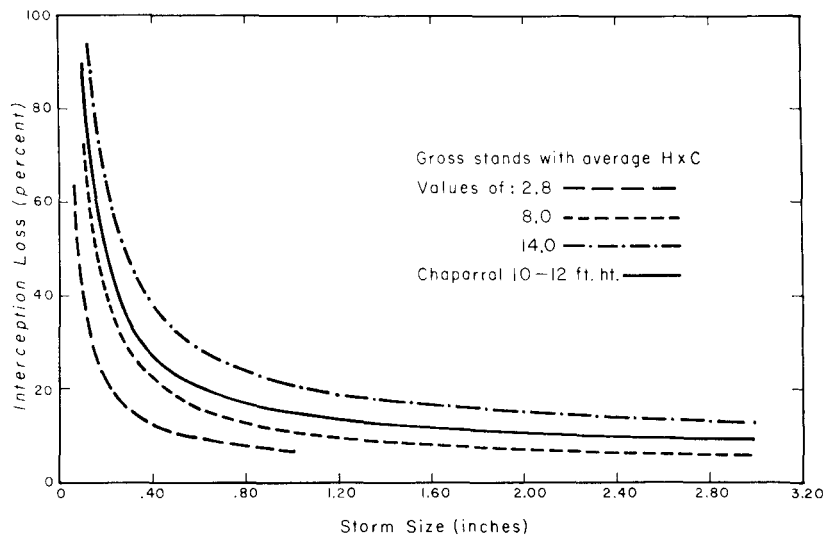


Figure 6.—Relationship of interception loss to vegetation cover and storm size, San Dimas Experimental Forest, California.

fall and winter. The plants will usually grow rapidly from February or March until the rains diminish in April or May. Thus much of the annual precipitation falls when the grass is in its lower stages of development. On an average about 67 percent of it falls when grass growth is represented by the $HxC = 2.8$ curve; 22 percent when growth is represented by the $HxC = 8.0$, and 11 percent when growth is represented by $HxC = 14.0$ curves.

Simple regression equations using storm size as the independent variable were computed for each HxC grouping. The relationship between grass interception loss ($\hat{I}_L$) and storm size (P), derived from storms greater than the interception storage capacity as determined by the HxC measurements, are given in *table 1*. For any storms smaller than the interception storage capacity the interception loss should approximate the rainfall input.

The equation derived by Hamilton and Rowe (1949) for estimating interception loss (in inches) from mature chaparral was:

$$\hat{I}_L = 0.062P + 0.083 \quad (4)$$

in which the first constant is the coefficient of evaporation from the vegetation and the second constant is the interception storage capacity. Their data give standard errors of estimate of 0.044 inch and 0.089 inch for storms under 3.00 inches and all storms up to 11.50 inches, respectively. Comparison of equation (4) with equation (3) in *table 1* suggests that the grass stand approaching maturity has a greater interception storage capacity than the chaparral—0.115 inch to 0.083 inch. In its early stages of development, grass interception storage capacity is considerably less than that of chaparral.

The only way to provide a meaningful comparison between interception losses for grass and chaparral, or for that matter a realistic estimate of an-

nual interception loss, is to apply actual yearly precipitation data to the established relationships on a storm by storm basis. In their work with chaparral, Hamilton and Rowe (1949) measured storms from 0.10 to 11.50 inches in size during an above-average rainfall period. Using the regression equations for grass this far beyond the range of observed data may be risky owing to the small number of large size storms measured, the tendency of the grass to lodge in large storms (especially when tall), and the difference in vegetative structure between grass and chaparral. For storms greater than 3.00 inches the interception loss for grass, as computed by the regression equations, was compared with interception loss as determined independently by extending the curves in *fig. 6* visually at a gradually decreasing slope. For the $HxC = 8.0$ and $HxC = 12.0$ curves the difference in interception loss as computed by the two techniques was less than 2 percent. As there were only 18 storms greater than 3.00 inches in the March through October period during the 32 years, these regression equations were used for the comparison. Equation 1 was used only for storms less than 1.00 inch. For larger storms interception loss during the November through February period was computed by extending the $HxC = 2.8$ curve in *fig. 6* at a slope similar to the $HxC = 8.0$ curve. As can be seen from *fig. 6* there is only a small change in slope with increasing storm size for the larger storms.

To estimate annual interception losses, precipitation data for a 32-year period were substituted in the regression equations on a storm basis. For storms in November through February, equation (1) or the extended curve representing $HxC = 2.8$ was used to determine the interception loss. For storms in March, equation (2) was used. For storms

Table 1.--Equations for estimating gross interception loss (in inches) over the range of storms measured for three stages of grass growth

Stage of grass growth	Regression equation	Std. error of estimate	r
		<i>inches</i>	
$HxC = 1.0-4.9$	$\hat{I}_L = 0.026P + 0.037$ (1)	0.023	0.9967
$HxC = 5.0-11.9$	$\hat{I}_L = 0.032P + 0.074$ (2)	.027	.9992
$HxC = 12.0-17.8$	$\hat{I}_L = 0.089P + 0.115$ (3)	.040	.9106

occurring in April through June, equation (3) was used. As the grass stand dries and begins to deteriorate in late spring and summer, its HxC values declined below those at maturity. Measurements made in fall indicate the middle curve for grass interception loss (*fig. 5*) would approximate the loss from standing dead grass. Thus for storms occurring in July through October, equation (2) was used. The results are at best, only an approximation of the growth stage of grass in any given year. As pointed out by Heady (1957) and Weihing (1963), growth of annual grass in a particular month can vary greatly between years.

Grass interception loss ranged from 5.0 percent in the 1953-54 Hydrologic Year to 13.8 percent in the 1963-64 Hydrologic Year. The low interception loss of 5.0 percent occurred in a year in which the bulk of the precipitation fell during the grass stage represented by the HxC 2.8 curve. Seventy-three percent of the rain that year fell in November, when the grass would have been in its lowest stage of development. The high interception loss of 13.8 percent in 1963-64 occurred in a year in which more than 50 percent of the precipitation occurred in March through June, when the grass was in its later stages of development.

The average annual interception from grass over a 32-year period was estimated at 7.9 percent. Chaparral interception loss ranged from 9.5 percent to 19.0 percent, and averaged 12.8 percent.

The interception loss for any individual year will depend on the stage of grass development as influenced by climatic conditions and by the time and size distribution of storms. When the bulk of the precipitation falls in many small storms the interception loss is high. For instance, if only storms under 3 inches during the 32-year period were considered, the interception loss for grass would be about 12.3 percent and that for chaparral 17.8 percent. But, when the bulk of the precipitation falls in a few large storms, this loss would be lower for both grass and brush.

Interception Loss from Litter

A substantial layer of litter lying flat on the soil surface is sometimes found on wildland areas and on ranges in good condition. To obtain an estimate of interception losses from such material, we divided litter samples into two groups: Group 1, averaged 1,650 pounds of grass litter per acre; the samples ranged from 1,000 pounds to 2,300 pounds per acre. Group 2 averaged 5,500 pounds per acre;

the samples ranged from 3,500 pounds per acre to 6,900 pounds per acre.

The amount of water evaporated from litter is governed primarily by the moisture-holding capacity of the litter and evaporation potential during and after the storm. The grass litter in group 2 absorbed .06 inch of rainfall, but only slightly over .01 inch of rainfall was stored by the litter in group 1 (*fig. 7*). The grass litter dried rapidly, losing most of its moisture by the end of the second day after a rain. Under natural conditions where the litter lies directly on a moist soil surface these drying curves would be expected to be less steep.

Interception loss increased as grass litter increased but not on a 1:1 ratio (*fig. 8*). Evidently the amount of rain that grass litter retains depends on the arrangement as well as amount of litter. A loosely packed litter layer probably has more effective surface area for water drops to cling to and presents greater opportunity for free air movement and evaporation. Interception losses from small storms were high; those for larger storms ranged between 2 and 5 percent. Litter interception can be estimated from the regression equations in *table 2*.

Applying the 32 years of rainfall data to the regression equations, we found that annual interception loss from grass litter ranged from 2.8 to 8.0 percent, and averaged 4.3 percent. In determining these values, equation No. 6 was used for storms in July through November (representing the period of maximum litter accumulation under natural conditions) and equation No. 5 for storms in December through June. In areas where the rate of litter decomposition is slow, it may be more realistic to use one equation for most or all of a year—depending on the litter amount. Not all grass litter decomposes each year so it may gradually accumulate over time in undisturbed areas (Heady 1956). The time of storm occurrence and the relative amount of precipitation in large or small storms is responsible for the differences in interception percentages from year to year.

The amount of water retained by seeds, dead leaves, and stems of grass accumulated during a 1-year period in the grass interception sampling collars ranged from .02 to .07 inch and averaged .046 inch. These values fall between those for the moisture retention capacities of the two groups of litter studied.

When dried grass decays or is beaten or trampled to the ground by wind and rain, cattle, and other sources, its capacity to intercept rain is then re-

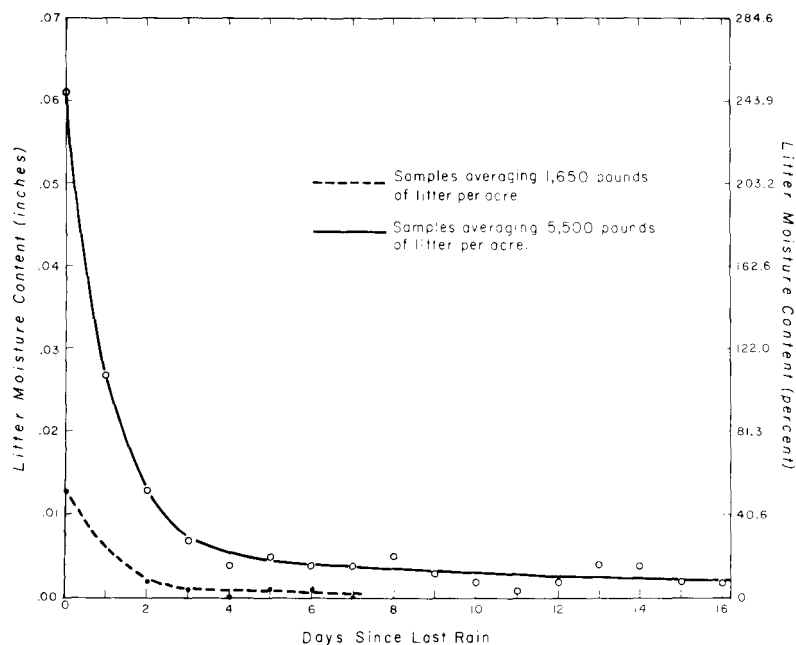


Figure 7.—Moisture content of grass litter dropped drastically with passage of time since wetting. Quantity of litter also affected moisture content. Plotted points represent average moisture content of litter at various time intervals after storms.

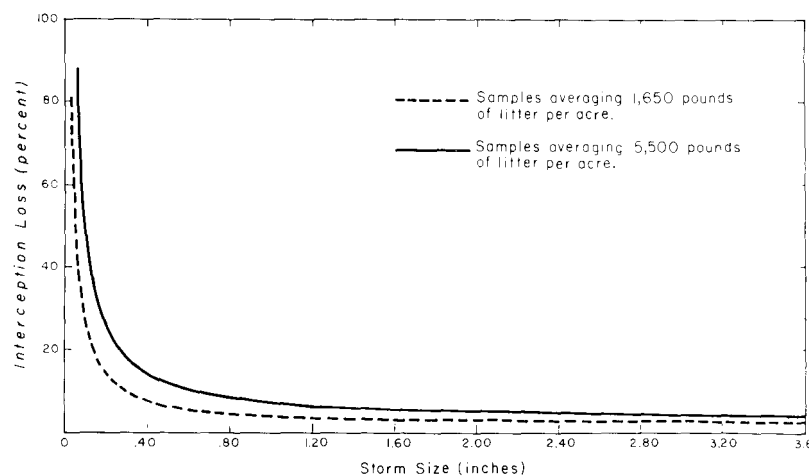


Figure 8.—Amount of rain intercepted by grass litter depends on amount and arrangement of litter.

Table 2.--Equations for estimating litter interception loss (in inches)

Litter sample	Regression equation	Std. error of estimate	r
<i>inches</i>			
Avg. of 1,650 lbs./acre	$\hat{I}_L = 0.015P + 0.025 \quad (5)$	0.013	0.8769
Avg. of 5,500 lbs./acre	$\hat{I}_L = 0.023P + 0.048 \quad (6)$	.021	.7589

Table 3.--*Distribution of annual interception losses for grass, chaparral, and grass litter, San Dimas, Experimental Forest, California*

Interception (percent)	Number of years		
	Grass	Chaparral	Grass litter
2.0 - 2.9	--	--	2
3.0 - 3.9	--	--	7
4.0 - 4.9	--	--	10
5.0 - 5.9	5	--	7
6.0 - 6.9	7	--	5
7.0 - 7.9	6	--	0
8.0 - 8.9	1	--	1
9.0 - 9.9	2	1	--
10.0 - 10.9	1	4	--
11.0 - 11.9	2	5	--
12.0 - 12.9	5	6	--
13.0 - 13.9	3	4	--
14.0 - 14.9	--	2	--
15.0 - 15.9	--	3	--
16.0 - 16.9	--	1	--
17.0 - 17.9	--	3	--
18.0 - 18.9	--	1	--
19.0 - 19.9	--	2	--

duced because it does not have as much surface area exposed to collect water droplets and expose them to evaporation. In annual grass areas, however, grass mulch and litter are the major sources of interception loss during fall and early winter storms.

The average annual litter accumulation for the chaparral types found on the San Dimas Experimental Forest ranged from 419 pounds per acre to 4,079 pounds per acre. The average annual accumulation was 1,323 pounds per acre (Kittredge 1939b).

The total amount of organic matter under the chaparral has been found to range from 6,439 pounds per acre to 46,702 pounds per acre on a dry weight basis. This amount includes all the organic accumulation down to mineral soil. Water

retained by the chaparral floor at field capacity ranged from 0.04 to 0.29 inch, amounts considerably greater than for grass litter. These amounts, less the actual moisture content at the beginning of rain, would be subject to evaporation from the chaparral floor and would not contribute to soil moisture (Kittredge 1939a).

Distribution of Interception Losses

The distribution of computed annual interception losses for grass, brush, and grass litter is given in *table 3*. In 18 out of the 32 years used in this analysis, estimated grass interception losses were between 5 and 8 percent. In 19 of the 32 years, chaparral interception loss ranged between 10 and 14 percent.

Discussion and Conclusions

As the grass stand developed throughout the rainy season the amount of estimated interception loss increased. The loss was high for small storms—especially in spring when warming temperatures stimulate grass growth. When precipitation comes in a series of small storms, interception by grass can be quite large. In Hydrologic Year 1963-64, for example, out of a total rainfall of 15.32 inches, the estimated interception by grass was 13.8 percent and by brush, 16.6 percent. Interception loss for large storms, especially if they occur early in

the growing season when grass is in its early stages of development, is relatively small. In Hydrologic Year 1953-54, 92 percent of the 24.92 inches fell in seven storms. The calculated interception loss from grass was 5.0 percent and from chaparral 10.9 percent.

Grass in its later stages of growth may give similar or even higher interception values than mature chaparral. In California, however, annual grass is in these stages for only a few months at the end of the rainy season. Chaparral vegetation, being ever-

green, can intercept a fairly constant amount of rainfall the year round. This characteristic accounts for its higher yearly interception values.

In years of average precipitation (26 inches), an estimated 1.3 inches in gross interception losses could be saved by converting from brush to grass at San Dimas. This estimate does not consider possible differences in litter interception. An average precipitation year is a theoretical term computed arithmetically. Actually in only 8 years out of 32 at San Dimas did the annual precipitation amounts fall between 22 and 32 inches. The savings would have ranged from 0.31 inch to 2.30 inches in the hypothetical cases evaluated in this paper. They would probably be even greater if the litter components of grass and chaparral are included. Besides reducing the rate of soil evaporation (Rowe 1955), the litter layer protects the soil from erosion and helps to retard surface runoff. Thus the value of the litter layer may outweigh the amount of inter-

ception loss under many conditions.

Cattle grazing reduces interception loss from grass by reducing the quantity of vegetation and thus, its interception storage capacity. The interception loss on grazing lands could be estimated by using the interception loss relationship which represents the grass conditions at the time of rain storms. A savings in soil moisture at the same time also would be realized because of the reduced transpiration by the shorter grass plants (Mitchell and Kerr 1966).

The net water loss to the watershed from grass or chaparral interception can only be surmised. Interception losses from non-transpiring surfaces, such as dead grass or brush stems, would certainly result in a net water loss to the watershed. The net water loss to the plant-soil-water system may not be as high as the gross interception measurements reported in this paper, but its amount is undoubtedly significant in the redistribution of precipitation.

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Loss of precipitation due to interception by annual grass and grass litter was measured during three rainy seasons on the San Dimas Experimental Forest, in southern California. Interception loss from annual grass averaged 7.9 percent; that from mature chaparral cover, 12.8 percent. If chaparral stands were converted to grass, an estimated 1.3 inches of gross interception could be saved each year.

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Retrieval Terms: precipitation interception; evapotranspiration; water yield; brush removal (-hydrology); plant water relations.

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