Evaporation from rangeland with and without honey mesquite

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Abstract

The Bowen ratio/energy balance technique was used to estimate evaporation (E) from honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa)* as the difference in total E (plant and soil) between that of adjacent mesquite-dominated and mesquite-free rangeland areas near Throckmorton, Tex. After treatment with diesel in July 1988 to defoliate the honey mesquite, E from the treated area decreased to a minimum value of about 40% of that from the untreated area. In 1989, seasonal E totals from the untreated and treated areas were, respectively, 190 and 176 mm—a 7% reduction in E due to mesquite defoliation. Total E for the herbaceous and honey mesquite vegetation in 1989 in the untreated area was 117 and 73 mm, respectively. Honey mesquite foliar cover was 15% in the untreated area, but it accounted for 38% of the total E. These honey mesquite E data were supported by independent measurements of sap flow. While honey mesquite used substantial amounts of water, E from the rangeland from which it was removed was just slightly lower due to increased herbaceous evaporation associated with increases in standing crop. Under the circumstances of low grazing intensity and low runoff potential, honey mesquite removal would provide little if any additional water for off-site uses in the short-term and, therefore, the removal of this species for purely hydrological purposes would not be justified. Increases in off-site water availability may, however, result from honey mesquite control under grazing regimes which preclude accumulation of additional herbaceous standing crop or at site with greater runoff potential

Key Words: *Prosopis glandulosa,* transpiration, evapotranspiration, sap flow, Bowen ratio/energy balance

As the demand for water increases (Anderson 1983), a critical question involves the effect of land management practices such as brush control on the water balance of rangelands. To understand how brush control might affect on-site water use efficiency and water availability for off-site uses, it is important to identify the effects of land management practices on rangeland hydrologic processes.

Evaporation (E), which includes plant and soil evaporation (Monteith 1985), is the largest water loss from rangelands and accurate E data are critical for evaluating the effect of management practices on rangeland hydrologic processes. However, few E data are available for rangelands, especially for brush species which compete with herbaceous vegetation for water.

Evaporation data for the widespread woody plant, honey mesquite *(Prosopis glandulosa* Torr. var. *glandulosa)*, are highly variable, depending, in part, upon the depth to available soil water (Thomas and Sosebee 1978). The data suggest that it is a facultative xerophyte. The limited evidence supporting the premise that this species competes for water that could be used for other purposes fosters the assertion that its removal would significantly increase water availability for other uses (McGinnies and Arnold 1939, Rechenthin and Smith 1967, Mosely 1983) even though the data are inconclusive (Griffin and McCarl 1989).

The objective of this study was to calculate honey mesquite E as the difference between E, measured using the Bowen ratio/energy balance technique (Tanner 1960), from adjacent mesquite-dominated and mesquite-free areas. These E values were compared with honey mesquite sap flow rates measured by heat balance gauges (Baker and van Bavel 1987).

Materials and Methods

Site Description and Experimental Design

This experiment was conducted during 1988 and 1989 at the Texas Experimental Ranch, 16 km north of Throckmorton (33° 20'N, 99° 14'W, elevation = 450 m). The slope of this upland site was < 1%. The predominant soil at the site (Heitschmidt et al. 1985) was a Nuvalde clay loam (fine silty, mixed, thermic Typic Calciustolls). Grazing intensity was 4 ha AUM^{-1}. Honey mesquite trees at the ranch had been chemically treated in 1979 and were characterized by a multi-stemmed regrowth pattern.

Evaporation measurements were made in 2 adjacent areas. One, termed untreated, had a mix of herbaceous vegetation and honey mesquite. The other, termed treated, had only herbaceous vegetation after the diesel application which defoliated all of the honey mesquite. On 27 July 1988, about 1 liter of diesel fuel was applied to the base of each honey mesquite tree in the 6-ha treated area (200 m east-west by 300 m). The untreated area was immediately to the south of the treated area and, for vegetation sampling purposes, was considered to be 200 by 200 m, although similar vegetation extended for more than 1 km in all directions.

Vegetation Sampling

On 28 May 1988, herbaceous standing crop in each area was estimated by clipping plants in 6 randomly positioned, 1- by 1-m quadrats at a height of 10 mm. On 25 Apr., 30 May, 6 July, 7 Aug., and 5 Sep. 1989, standing crop was clipped by species, except on the last day, from three 1-m square quadrats at 5 sampling locations in both areas (n = 15). Samples were dried and weighed. On 5 Sep. 1989, density of woody plants in both areas was estimated by the point centered-quarter method (Cottom and Curtis 1956) at 25 points uniformly distributed across each area, and canopy height and diameter of 100 individual honey mesquite trees in the untreated area were measured.

Photosynthetically active radiation (PAR) above and below the honey mesquite canopy was measured on 13 Apr., 10 May, and 29 July in 1988 and on 25 Apr., 14 July, and 22 Sept. in 1989 using a Model LI191SB sensor (LiCor Corp., Lincoln, Neb.). Four, 30-m long transects were established in both areas at 30-m intervals. Measurements of below-canopy PAR were made within 2 hours of solar noon for 60 s each at 1-m intervals along each transect with the sensor centered upon and normal to the transect at a height below the honey mesquite and above the herbaceous canopy.

Bowen Ratio/Energy Balance

Existing mesquite E data are based primarily upon measurements of gas exchange on small leaf samples or soil water content. Gas exchange measurements may be inaccurate or unrepresentative because of the effect of the sensor on the leaf boundary layer and because of the need to extrapolate to the whole plant over the day measurements made on small portions of a canopy during brief periods of time. The E estimates from soil water measurements,

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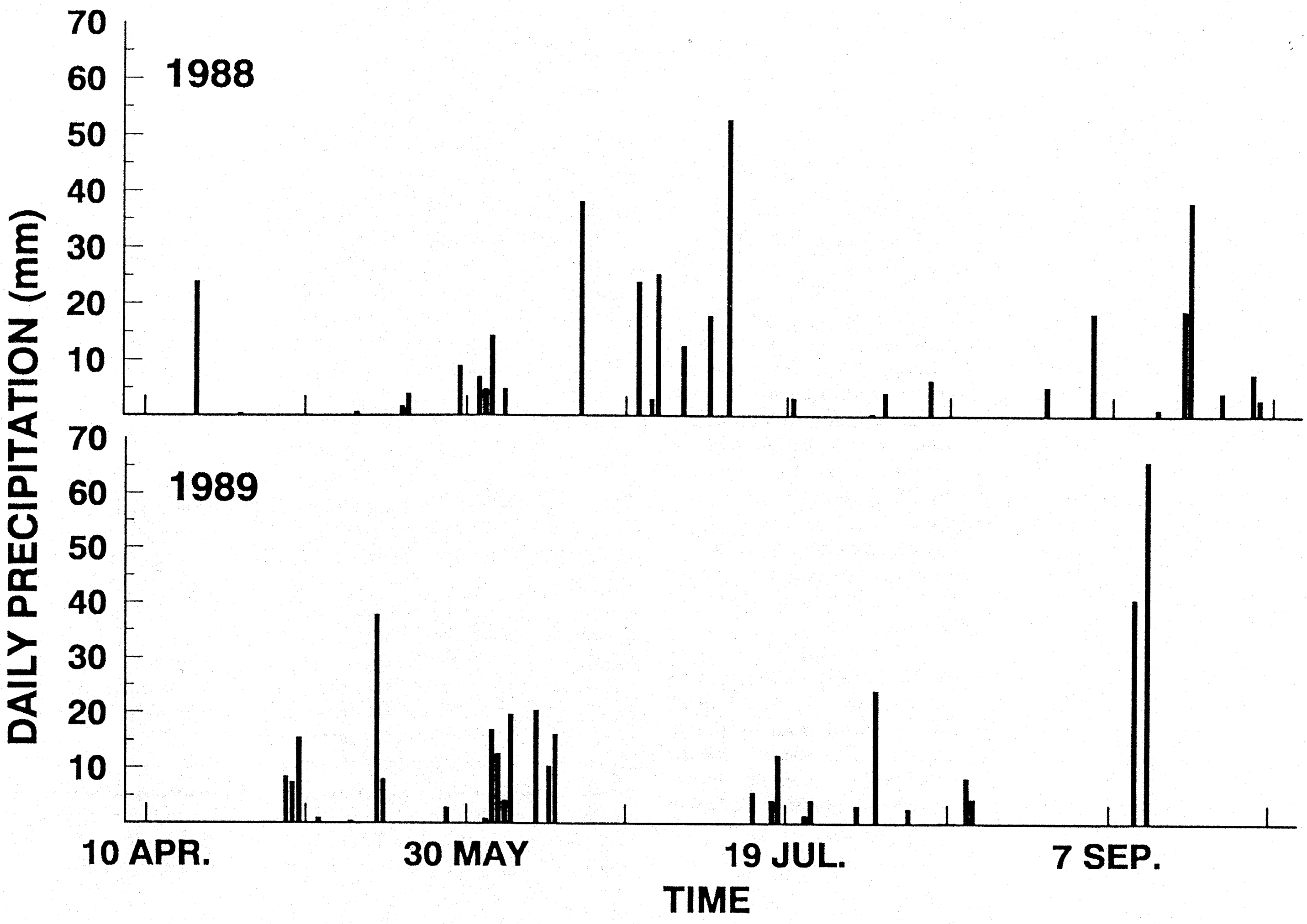

Fig. 1. Daily precipitation in 1988 and 1989 at the experimental site near Throckmorton, Texas.

calculated as a residual from the water balance, include the measurement error of other hydrologic components, which can be large, and are inaccurate for short periods. Neither method necessarily provides representative E measurements for extensive stands (Waisel 1960, Van Hylckama 1974, Thomas 1976). However, the Bowen ratio/energy balance (BREB) technique can provide accurate, continuous measurements of E over an extensive area. Its use requires a long upwind distance of uniform conditions (fetch); this is typically not limiting on rangelands.

In 1988, BREB measurements were made during 3 periods: 11 April through 27 May, 26 July through 19 August, and 7 through 30 September. In 1989, BREB measurements were made during 2 periods: 25 April through 13 July, and 23 August through 25 September.

The energy balance of the 2-dimensional earth's surface, ignoring the very small amount of energy used in photosynthesis, can be described by:

$$Rn = LE + H + G \qquad (1)$$

where Rn is the net radiation, L is the latent heat of vaporization, and H and G are the sensible and soil heat fluxes, respectively. The sign convention used herein was that Rn toward the surface and LE, H, and G away from the surface were positive.

If temperature (T) and specific humidity (q) measurements are made at a minimum of 2 heights with the same vertical distance between the sensors, the Bowen ratio (BR) can be calculated as

$$BR = (Cp/L)*(Kh/Kw)*(dT/dq) \qquad (2)$$

where Cp is the specific heat of dry air at constant pressure and Kh and Kw are the transfer coefficients for heat and water vapor, respectively. If it is further assumed that (1) Kh = Kw, (2) the vertical profile shapes of T and q are similar, and (3) the vertical flux is constant over the heights where T and q are measured, equations (1) and (2) can be combined into the following

$$E = [(Rn-G)/(1+BR)]/L \qquad (3)$$

Except in extremely unstable or stable atmospheric conditions, assumption 1 is usually valid (Rosenberg et al. 1983). Assumptions 2 and 3 are typically not violated if measurements are made at appropriate heights above the surface. Adequate accuracy of the BREB technique has been demonstrated by comparison with E measurements from lysimeters (Tanner 1960, Denmead and McIlroy 1970, Blad and Rosenberg 1974) and the technique has been successfully used in natural communities (McNaughton and Black 1973, Gay and Holbo 1974, Gay and Fritschen 1979, McCaughey and Brintnell 1984).

The Rn was measured at both a base station and a mobile station in each area. The Rn in 1988 was measured with 1 Model 6220 and 3 Model 6211 net radiometers (Science Associates, Princeton, N.J.) at heights of about 3 m. The mobile station in the treated area did not have a net radiometer for the last 2 measurement periods in

1988. In 1989, 1 Model 6220, 2 Model 6211, and 1 Model Z002886 (REBS, Seattle, Wash.) radiometers were used. The 6220 was on the base station in the untreated area in both years and measurements from it were used in the LE calculations for all stations [Eq. (3)] because the relationship between it and Rn measured at other stations was consistent (see below).

Near each base station, soil heat flux was calculated from measurements from 4 soil heat flux plates buried at 0.1 m (1988) or 0.05 m (1989), and from storage above this depth. Storage was calculated from soil temperature and heat capacity above the plate depth. Plate measurements were corrected for plate shape and differences in soil and plate conductivity (Philip 1961). Three plates were buried away from and 1 plate was buried under a honey mesquite tree in each area. Soil temperature was measured with spatially averaging, copper/constantan thermocouples buried 0.2 m from each plate. The heat capacity was determined from bulk density and gravimetric soil water content measurements of 75-mm diameter soil cores (4 to 6 per area) taken about every week.

Measurements of dT and dq were made on both base and mobile stations with systems similar to the design of Tanner et al. (1987) and Bingham et al. (1987). The dT was measured at heights of approximately 2.8 and 4.0 m above the ground by 2 pairs of unaspirated, unshielded, differentially wired, chromel/constantan thermocouples (wire diameter at junction = 25.4 μm). The dq values were calculated from dew point temperature (Tdp) measured on air drawn from each air temperature height to a Model DEW 10 cooled-mirror, dew point hygrometer (General Eastern, Watertown, Mass.). The Tdp was converted to q (Geiger 1973). The air stream from each height was switched to pass over the hygrometer every 60 s.

Measurements of dT and Tdp were made during the last 30 s of 60-s periods using a data logger that sampled every 2 s. Two 30-min means of the BR were calculated from the mean value of 2 dT measurements and from the difference in the mean q value for each height. Thus, there were 2 E values per station, with the Rn, G, and dq values common to each [Eq. (3)]. Daylight E totals were summed from half-hour E values. Daylight periods were typically 0800 through 1900 h Local Standard Time. This encompassed the time during which almost all the E occurred.

The base station in the treated area was located about 50 m south of the center of the northern border. The base station in the untreated area was located about 20 m south of the southern border of the treated area. In the treated area, this provided about 300 m of fetch for the predominantly southerly winds. This fetch distance is adequate for these Bowen ratio/energy balance calculations of E (Heilman et al. 1989).

To describe the spatial variability of the BR and Rn measurements, the mobile station in each area was moved about every 4 days to a different location. The mobile station was moved from 5 to 20 m each time in all directions and it remained within about 60 m of the base station. All stations were in the treated area until 29 April 1988.

Daylight totals of herbaceous E from the untreated area were calculated as the product of the mean E from the treated area (n = 4, 2 values/station) and the ratio of the herbaceous standing crop in the untreated and treated areas. Daily standing crop ratios were linearly interpolated from values calculated on sampling dates. This calculation of mesquite E assumes that herbaceous E was proportional to the standing crop. Honey mesquite E in the untreated area was the difference between the total E and herbaceous E in the untreated area.

At the base station in the untreated area, half-hour averages of wind direction were measured. Half-hour totals of precipitation were measured at all stations. Wind direction and precipitation were recorded for the same periods that BREB measurements were made. Daily precipitation was also measured throughout the year with a nonrecording raingage located approximately 300 m west of the base station in the treated area.

Honey Mesquite Sap Flow

Another technique applicable for honey mesquite E measurements is the constant-power heat balance gauge where sap flow rate through a stem is determined by a heat balance. From 27 July through 9 Aug. 1988, 2 sap flow gauges (Model SGA16, Dynamax, Houston, Tex.) were placed on 2 honey mesquite stems with diameters of about 17 mm on a tree near the base station in the treated area. In 1989, sap flow was measured near the base station in the untreated area on 9 honey mesquite stems from 26 April through 13 July and on a different set of 9 stems from 23 August through 25 September. For both periods, 8 of the 9 stems had diameters from 15 to 20 mm (gauge Models SGB16 and SGB19) and 1 had a diameter of 35 mm (Model SGA35).

Gauge signals were sampled every 15 s, and 30-min averages were calculated by a data logger. Daylight totals of mass flow were summed from 30-min sap flow values calculated following the procedures described by Dugas (1990). Gauges provide accurate measurements of sap flow rates of agronomic (Dugas 1990) and woody plants (Steinberg et al. 1989).

Prior to use in the field, sap flow measurements using gauges were validated in the glasshouse by comparison with mass measurements from a potted honey mesquite plant whose soil surface was covered to eliminate soil evaporation. Measurements were made at Temple, Tex., for 4 days in February 1988. Total measured mass loss and calculated sap flow were 1,335 and 1,387 g, respectively. The root mean square error (RMSE) of the daily losses was 25 g. These results confirmed the method accuracy for honey mesquite.

On 14 July 1989, the area of all leaves on each gauged stem was estimated. All leaves were stripped from each stem and approximately 10% of the leaf area was measured with a photo-electric leaf area meter. Leaves were dried and the total leaf area for each stem was calculated from the ratio of leaf area to leaf mass of the subsample and the mass of the remainder of the leaves.

Results and Discussion

Vegetation

Honey mesquite responded immediately to the diesel application on 27 July 1988. Leaves wilted within 2 days of application, and about 90% of the trees were completely defoliated by 7 September. Honey mesquite density in the treated and untreated areas was 380 and 486 trees ha^{-1}, respectively. In the untreated area, average tree height and crown diameter were both 1.99 m, and honey mesquite foliar cover was 15.5%. On 5 September 1989, 4% of the honey mesquite plants in the treated area exhibited a small amount of regrowth. In the treated and untreated areas, lotebush [*Condalia obtusifolia* (Hook.) Weberb.] made up 1 and 5% of the woody species, respectively. Surviving honey mesquite and lotebush were retreated in the fall of 1988 and the spring of 1989. The likely small contribution of the honey mesquite regrowth and lotebush to E was ignored.

The minimum ratio of PAR below the honey mesquite canopy to that above was 0.85 in the treated area (before diesel application) and 0.9 in the untreated area. The ratio in the treated area in 1989 was about 1.0. Thus, a relatively small amount of energy was intercepted by the honey mesquite in both areas and essentially no energy was intercepted by honey mesquite stems in the treated area after diesel application.

In 1988, herbaceous standing crops in the treated and untreated areas (Table 1) were not significantly different ($P \leq 0.01$) and it was assumed that herbaceous E in the treated and untreated areas was

Table 1. Herbaceous standing crop in an area treated to defoliate honey mesquite and an untreated area in 1988 and 1989.

Area	Date					
	1988	1989				
	28 May	25 Apr.	30 May	6 July	7 Aug.	5 Sept.
	(kg ha^{-1})					
Treated						
avg	1020	632	1029	1152	715	928
SD	100	190	205	242	155	135
Untreated						
avg	830	477	692	613	461	797
SD	340	150	164	251	188	312

equal. In 1989, however, standing crop in the treated area was significantly greater on all sampling dates except the last, and herbaceous E in the untreated area was calculated as described above.

Texas wintergrass [*Stipa leucotricha* Trin. & Rupr.], buffalograss [*Buchloe dactyloides* (Nutt.) Englem.], and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] contributed 80 to 90% of the above-ground herbaceous biomass in both areas. The species composition in each area was similar in 1989. On 25 April, the difference between the 2 areas in percentage composition (by mass) was 2, 8, and 4% for these 3 species, respectively. On 7 August, differences were 8, 1, and 13%, respectively.

Bowen Ratio/Energy Balance

Precipitation totals for the periods defined by the beginning and ending dates of the BREB measurements (11 April and 30 September 1988, and 25 April and 25 September 1989) were 378 and 363 mm in 1988 and 1989, respectively. The long-term average precipitation at Throckmorton for the period from April through September is 457 mm. In 1988, larger daily precipitation totals occurred in late June and early July, while in 1989 the larger totals were in late May, early June, and mid September (Fig. 1). Daily precipitation totals varied significantly, occasionally by a factor of 2, between the 4 BREB stations, especially on days with large totals.

In 1988, wind direction was consistently from the south and southeast, especially during the second and third measurement periods. In 1989, wind direction was from the south and southeast during the first period. It was consistently from the south during the first 10 days of the second period and from the north or south during the last 15 days of the second period. These wind directions provided adequate fetch on almost all days to ensure that dT and dq measurements were representative of the respective areas.

In 1988, mean daylight Rn at the base station in the untreated area for the 3 measurement periods was 12.2, 12.0, and 8.9 MJ m^{-2}, respectively. In 1989, Rn for the 2 measurement periods was 12.4 and 8.7 MJ m^{-2}.

The ratios of Rn from the radiometers on the 2 mobile stations and on the base station in the treated area to the Rn from the radiometer on the base station in the untreated area (considered a 'standard' in this experiment) were used to evaluate the spatial variability of Rn and, in 1988, the effect of defoliating honey mesquite on Rn. The magnitude of the Rn ratios (Fig. 2) varied because of different radiometer designs. The variability of the ratio was small and comparable for all sensors; the C.V. of the ratios varied from only 3 to 6%. There was as much variability in the ratio of the radiometer on the base station in the treated area as for the radiometers on the 2 mobile stations, which, as a result of movement, 'viewed' different surfaces. This suggests that there was little spatial variability of Rn at this location. Because of the small variation in this Rn ratio for each sensor and of the large difference in the absolute Rn values for the different sensor designs, the Rn from the radiometer on the base station in the untreated area was used in all LE calculations [Eq. (3)].

There was no significant effect of honey mesquite defoliation on Rn in the treated area. After diesel application in 1988, Rn ratios increased for the mobile station in the untreated area, where no diesel was applied, and for the base station in the treated area (Fig. 2).

The soil heat flux was a relatively large percentage of Rn. In 1988, daylight G totals for the last 2 periods in the untreated area averaged 1.9 and 1.4 MJ m^{-2}, while the comparable values in the treated area were 2.0 and 1.8 MJ m^{-2}. In 1989, averages for the 2 periods were 2.0 and 1.6 MJ $^{-2}$ in the untreated area and 2.4 and 1.8 MJ m^{-2} in the treated area. The lower G values in the untreated area were caused by greater interception of Rn by the honey mesquite leaf area. These G differences are significant considering the magnitude of the E differences between the treated and untreated areas (see below).

Daylight E values from the base and mobile stations in the treated and untreated areas were essentially equal for the 2 years (Fig. 3). The slopes of linear regression of the mobile station E vs. base station E were not significantly different from 1.0 in either year for the untreated area ($P \leq 0.01$; Neter et al. 1985), but were significantly less than 1.0 in the treated area. The latter suggests that E values from the base station in the treated area may have been biased high. This would tend to have lowered the estimate of mesquite E. The E differences between the base and mobile stations were, however, quite small. In 1989, average E from the base and mobile stations differed by less than 0.08 mm d^{-1} for both areas. The RMSE between the E values from the base and mobile stations was 0.36 and 0.26 mm d^{-1} for the untreated and treated areas, respectively. The greater variation in E from the untreated area was likely due to the presence of honey mesquite.

In both years, early-season E values were most variable, primarily due to varying Rn, and total E values from the treated and untreated areas were essentially equal (Fig. 4). Early-season E values were lower in 1988 than in 1989 because of less precipitation (Fig. 1) and increased in both years following significant precipitation events. Maximum E was about 5 mm d^{-1} (Fig. 4). The E approached zero in both areas in 1988 and equaled zero in the treated area during dry conditions late in the 1989 growing season. The E rates on these mesic rangelands were low relative to those reported from agronomic crops (Tanner 1960, Blad and Rosenberg 1974), averaging slightly less than 2 mm d^{-1} over the 2 growing seasons.

For days in 1988 when BREB measurements were made, seasonal E totals were 119 and 106 mm from the untreated and treated areas, respectively. After diesel application in 1988, the values from these 2 areas were 62 and 45 mm, a 28% reduction in E in the treated area. For days in 1989 when BREB measurements were made, seasonal E totals were 190 and 176 mm from the untreated and treated areas, respectively, a 7% reduction in E. The lower reduction in 1989 of E in the treated area relative to that from the untreated area is attributed to higher E in the treated area associated with the increased herbaceous standing crop following elimination of competition by honey mesquite (Table 1). Damage to the herbaceous vegetation in the treated area under mesquite trees in 1988 caused by diesel application and trampling by the dozen individuals applying the diesel may also have been a factor. The 7% difference in E measured in this study between brush-dominated and brush-free rangelands is about one-half of the difference measured in a previous study (Richardson et al. 1979), but is similar to the difference measured for 2 years in south Texas from nonweighing lysimeters (Weltz 1987).

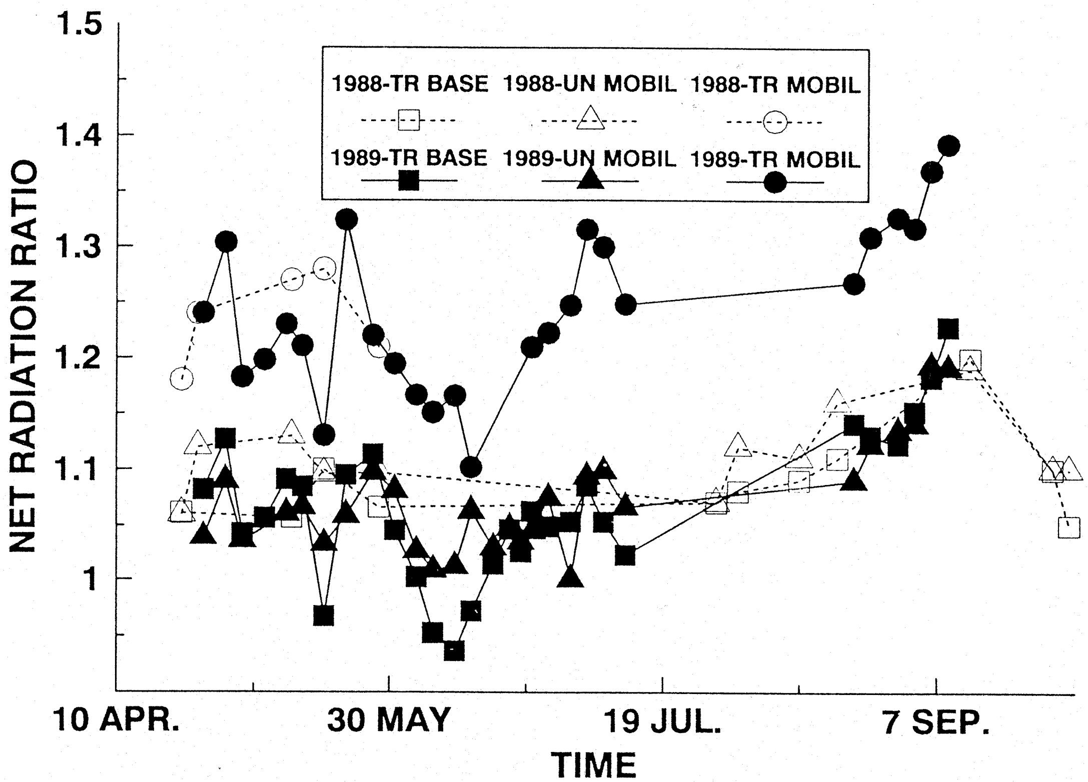

Fig. 2. Ratio of daylight net radiation from net radiometers on mobile stations in the treated (TR) and untreated (UN) areas and on the base station in the treated area to the net radiation from a radiometer on the base station in the untreated area in 1988 and 1989. Ratios were calculated for periods defined by mobile station movements (see text).

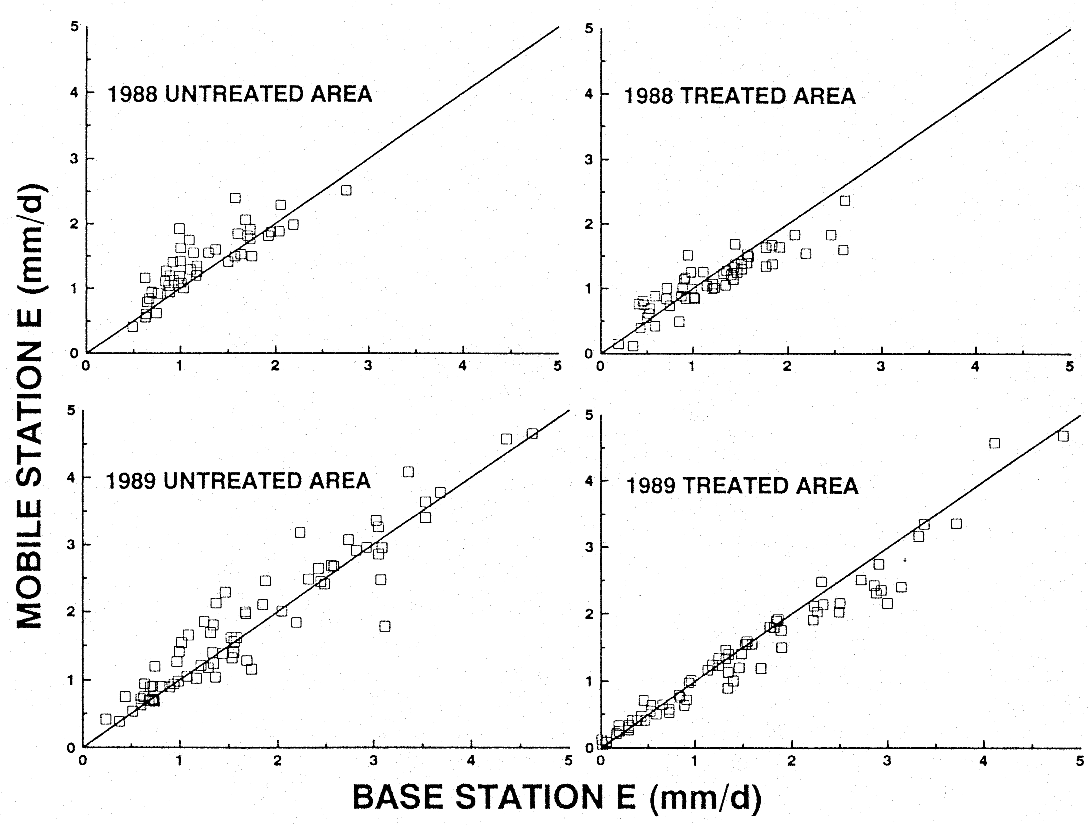

Fig. 3. Daylight totals of evaporation (E) from base and mobile stations in treated and untreated areas in 1988 and 1989. The 1:1 line is shown.

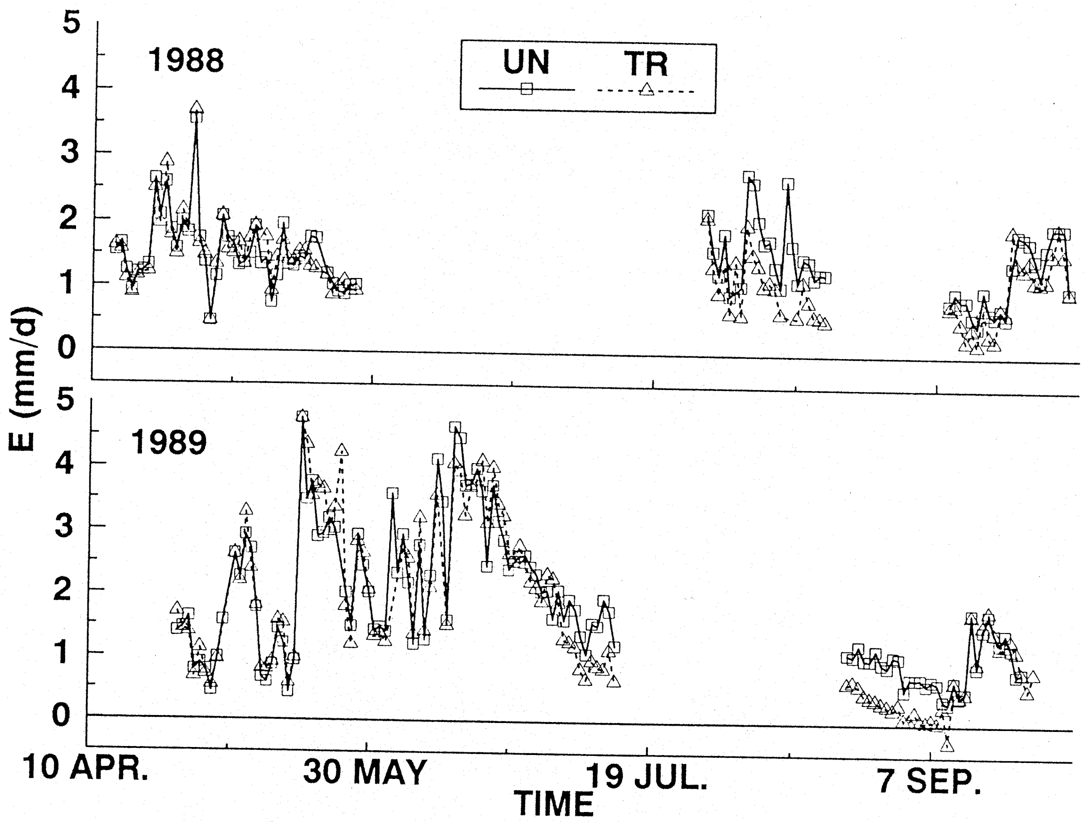

Fig. 4. Daylight totals of evaporation (E) in treated (TR) and untreated (UN) areas in 1988 and 1989.

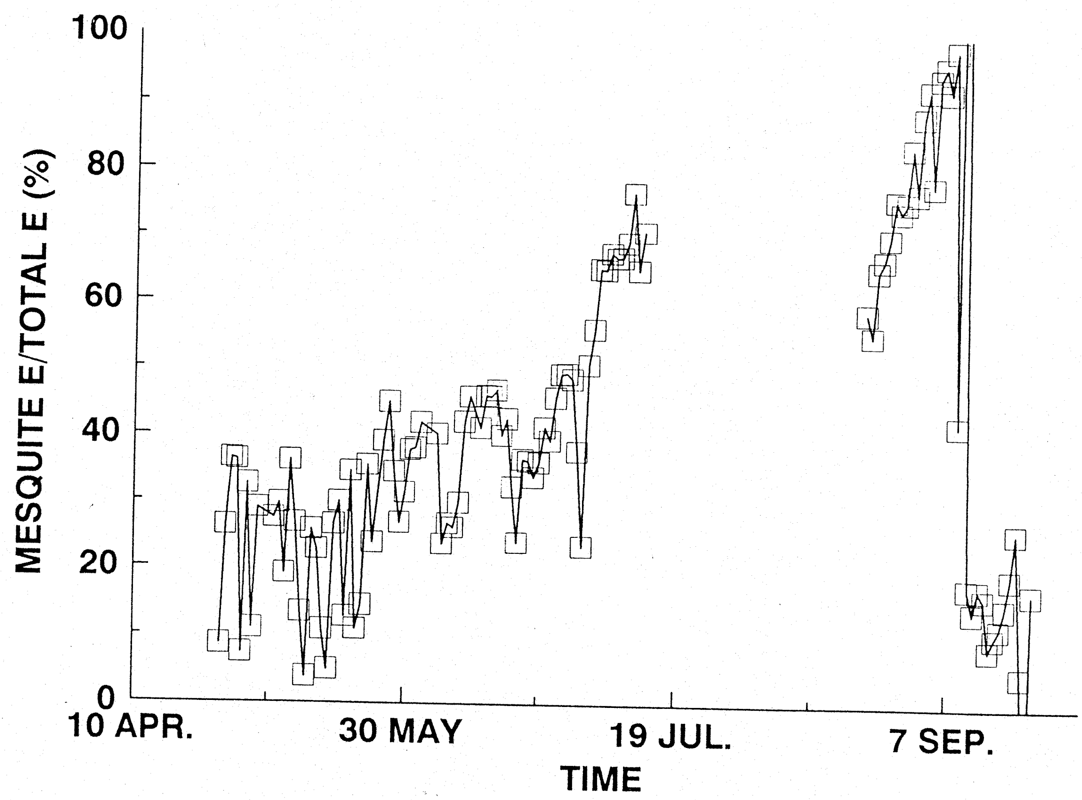

Fig. 5. Daylight evaporation (E) from honey mesquite expressed as a percentage of total E from the untreated area in 1989.

Honey mesquite E was consistently a smaller percentage of total E from the untreated area for the first half of the first measurement period and for the last 10 days of measurements in 1989 (Fig. 5). Increasing percentages from approximately 22 June to 14 July coincided with E values linearly decreasing (Fig. 4) in association with the lack of precipitation (Fig. 1), and may reflect the relatively low sensitivity of honey mesquite and high sensitivity of herbaceous vegetation to decreasing water availability in the upper soil profile. Honey mesquite E remained a high percentage of the total E throughout the beginning of the second measurement period until the heavy precipitation around 12 September. In 1989, total E for the herbaceous and honey mesquite vegetation in the untreated area was 117 and 73 mm, respectively. Even though honey mesquite had only 15% foliar cover and intercepted an even smaller percentage of the light, it contributed 38% of the seasonal E, and, during dry periods, up to 100% of E (Fig. 5). This relatively high contribution of honey mesquite to the total E may reflect its deep rooting pattern (Heitschmidt et al. 1988), which enables it to explore a large volume of soil for water.

The consistency of the E measurements from the BREB instrumentation and the effect of honey mesquite defoliation on E can be seen by examining the ratio of E from the treated area to that from the untreated area (Fig. 6). The E ratio varied $\pm$ 0.1 from 1.0 through 28 April 1988, when all 4 stations were near the base station in the treated area, and the ratio varied ± 0.2 from 1.0 for the remainder of the first period when there were 2 stations in each area, but before the diesel had been applied. Thus, the 4 Bowen ratio stations measured the same E when they were in the same area and the E values from the 2 areas were essentially equal before diesel application. For the first measurement period in 1988, the slope of the E ratio regressed against time was not significantly different from zero (two-tailed *t* test, $P \leq 0.005$; Neter et al. 1985). Subsequent to diesel application, the ratio dropped rapidly to a value of about 0.4. During the last period in 1988, the ratio was consistently less than 1.0 again, but fluctuated more than it did during the second period, likely because of larger precipitation totals (Fig. 1) and a concomitantly larger relative contribution of herbaceous vegetation to the total E (Fig. 5).

In 1989, the ratio of E from the 2 areas varied ± 0.2 from 1.0 for the first part of the season (Fig. 6). Beginning on about 29 June the ratio dropped rapidly to about 0.5 on 14 July, indicating the evaporation from the treated area was 50% of that from the untreated area. This period of rapid decrease coincided with declining soil water levels due to the lack of precipitation (Fig. 1) and with the increase in the honey mesquite E as a percentage of total E (Fig. 5). During the last measurement period in 1989, the ratio approached zero as the herbaceous component of E dropped to zero (Figs. 4 and 5). The maximum absolute difference in E between the 2 areas was approximately 0.6 mm d^{-1} and was also greatest during the last part of the first measurement period and the first part of the second period. The ratio again approached 1.0 after heavy precipitation.

Honey Mesquite Sap Flow

The rapid effect of diesel application on sap flow rate was evident in the daylight flow totals measured by the 2 gauges on a tree that had diesel applied to the base of it on 28 July (Fig. 7). Sap flow through the stem with the first gauge decreased from 700 g d^{-1} to less than 100 g d^{-1} within 9 d. The decrease is also reflected in data from the other stem. These data support the rapid decrease in E from the treated area, relative to that from the untreated area, as measured by the Bowen ratio instrumentation (Fig. 6).

In 1989, daylight stem flow totals from honey mesquite (Fig. 8) mirrored the E from the untreated area (Fig. 4). Both increased markedly on about 20 May in association with 50 mm of precipitation (Fig. 1) and both declined for the last 20 days of the first period. Sap flow declined markedly from the beginning of the second period until precipitation on about 12 September. The average sap flow through each stem was 1,368 g d^{-1}. Assuming sap flow through each stem was 1,000 g d^{-1} for the 40 days between the 2 sap flow measurement periods in 1989 (Fig. 8) and an arbitrary but representative 8 stems $tree^{-1}$, a total seasonal (150 days) water use of about 1,600 liters $tree^{-1}$ was calculated from the sap flow measurements. Using the 73 mm of honey mesquite E for the period of BREB measurements and the density of 486 trees ha^{-1}, and assuming that honey mesquite used 60% of an estimated 1 mm d^{-1} from the untreated area for the period between the BREB measurements (Figs. 4 and 5), calculated total seasonal honey mesquite E from the BREB measurements was 2,000 liters $tree^{-1}$. These estimates of mesquite E agree reasonably well with each other, but are substantially greater than the value of 80 liters $tree^{-1}$ calculated for upland range sites (Sosebee 1980).

Sap flow data also compare favorably with the seasonal E value of 100 liters m^{-2} of mesquite leaf area of Nilsen et al. (1983). Division of the average sap flow for each stem for the first measurement period by the total leaf area (both sides) yielded a mean E value for mesquite of 1.1 liters d^{-1} m^{-2} leaf area. This value was biased slightly because the leaf area was likely lower in the early part of the season than on the day leaf area measurements were made. This value was prorated for the entire 1989 season based upon the ratio of the mean daily E from the untreated area for the first measurement period to the mean daily E for the total season. This 'adjusted' sap flow per unit leaf area was 0.9 liters d^{-1} m^{-2} leaf area, which, for a 150-day season, resulted in a total water loss of 135 liters m^{-2} leaf area, a value slightly higher than that of Nilsen et al. (1983). As an additional comparison, using the assumed 8 stems $tree^{-1}$ and the measured value of 1.88 m^2 of leaf area $stem^{-1}$, the seasonal sap flow total of 1,600 liters is equivalent to 106 liters m^{-2} of leaf area.

As a final comparison between the sap flow and BREB E values, mean daylight sap flow totals were converted to a unit area basis, assuming 4,000 stems ha^{-1} (500 trees ha^{-1} and 8 stems $tree^{-1}$) and was divided by the total E from the untreated area. There were similarities between this sap flow/E ratio (Fig. 9) and the honey mesquite E expressed as a percentage of total E (Fig. 5). Both curves show a steep slope for the last half of the first measurement period, high values for the first half of the second period, and a rapid drop after the precipitation on about 12 September. Thus, the sap flow and BREB E measurements were in agreement.

Conclusions

Daily total evaporation (E) from rangeland was highly variable, differing by as much as a factor of 5 on successive days. Mesquite E was equally variable, whether estimated by Bowen ratio/energy balance or sap flow techniques. Mesquite E varied by as much as an order of magnitude on successive days and commonly varied by a factor of 3 or 4. Such extreme short-term variability has implications regarding the representativeness of E values estimated with methods that depend upon a limited number of measurements, each made over a brief period of time, such as porometry.

After diesel application in 1988 to defoliate all honey mesquite in the treated area, total E from the untreated and treated areas was 62 and 45 mm, respectively. In 1989, seasonal E totals from the untreated and treated areas were 190 and 176 mm, or a 7% reduction in E in the area without mesquite. Even though honey mesquite foliar cover was only 15% and it intercepted a small percentage of the light, honey mesquite E was 38% of the seasonal total in a year of average rainfall. During dry periods, honey mesquite E increased to 100% of that total. Both percentage and absolute differences in E between the treated and untreated areas were greatest under dry conditions and were essentially zero immed-

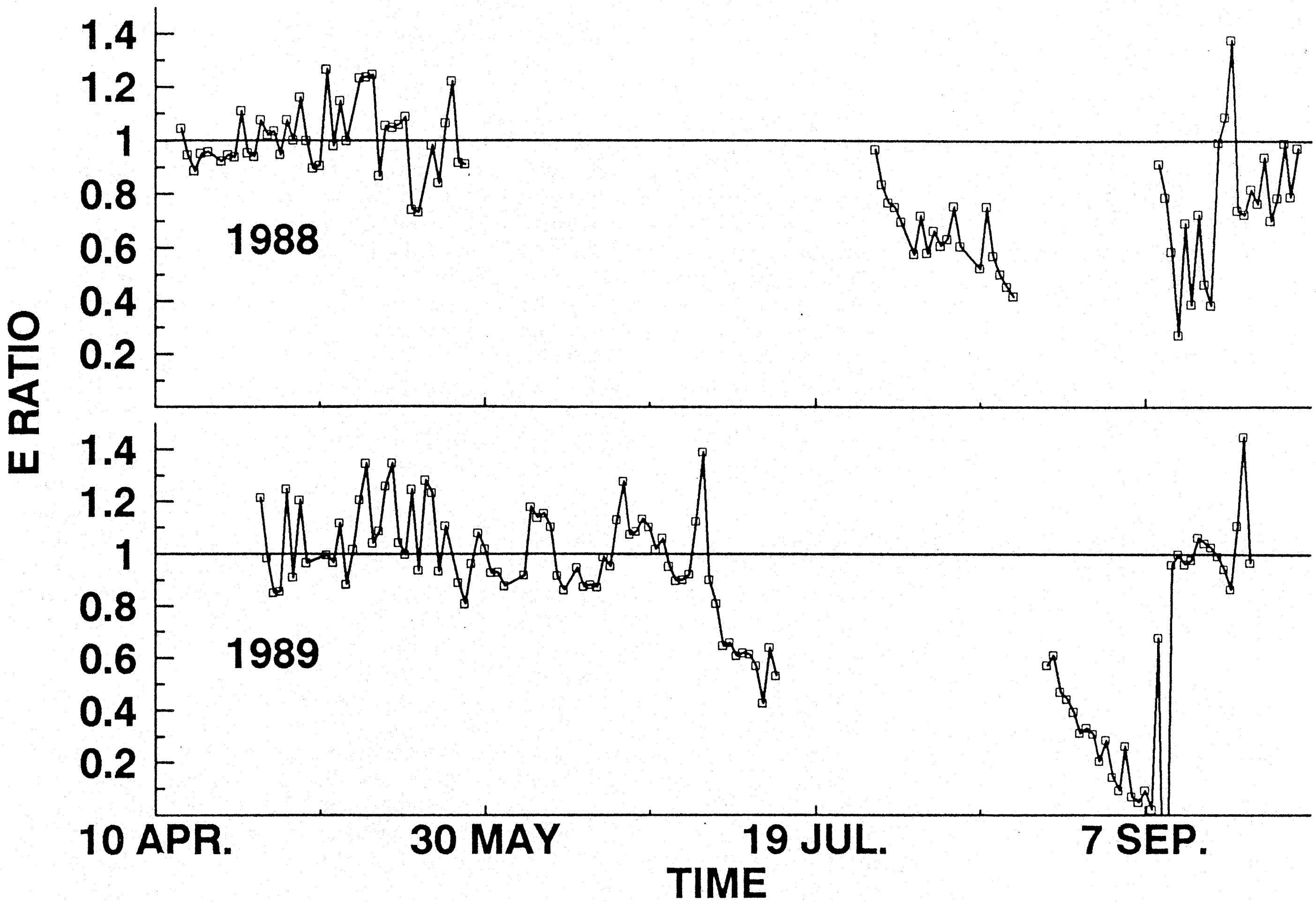

Fig. 6. Ratio of evaporation (E) from the treated area to the E from the untreated area in 1988 and 1989.

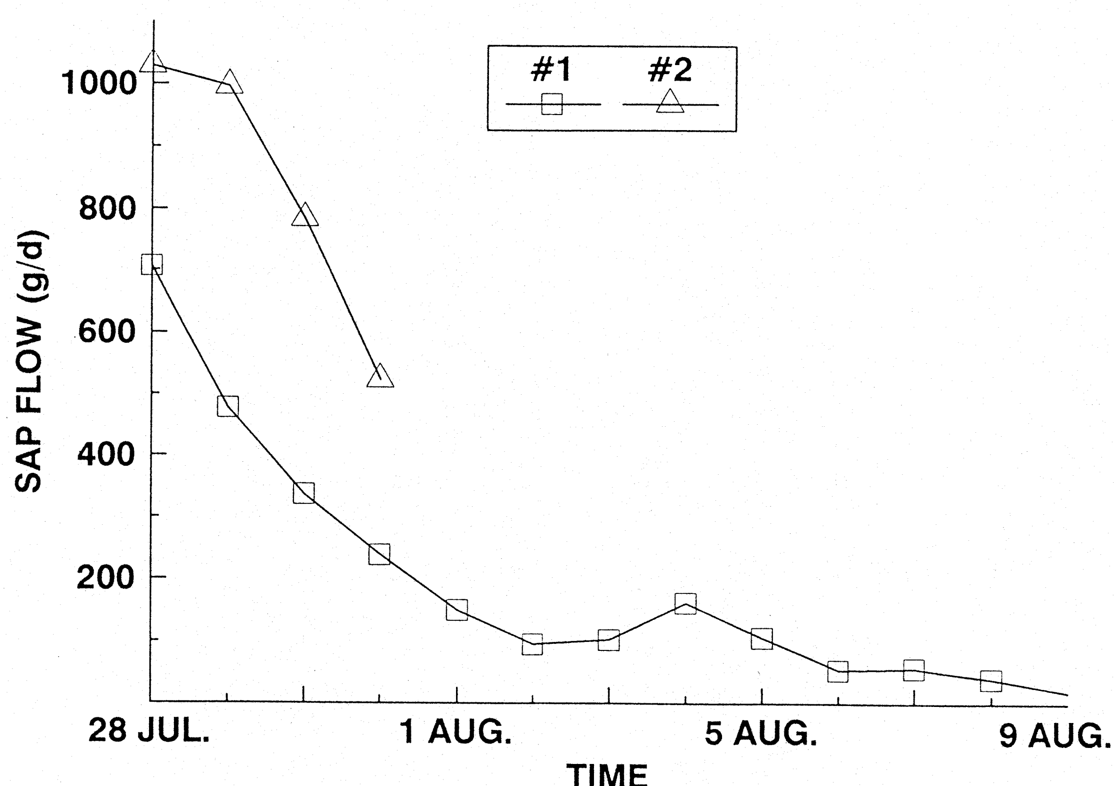

Fig. 7. Daylight honey mesquite sap flow from 2 gauges on 2 stems on a tree that had diesel applied to it on 28 July.

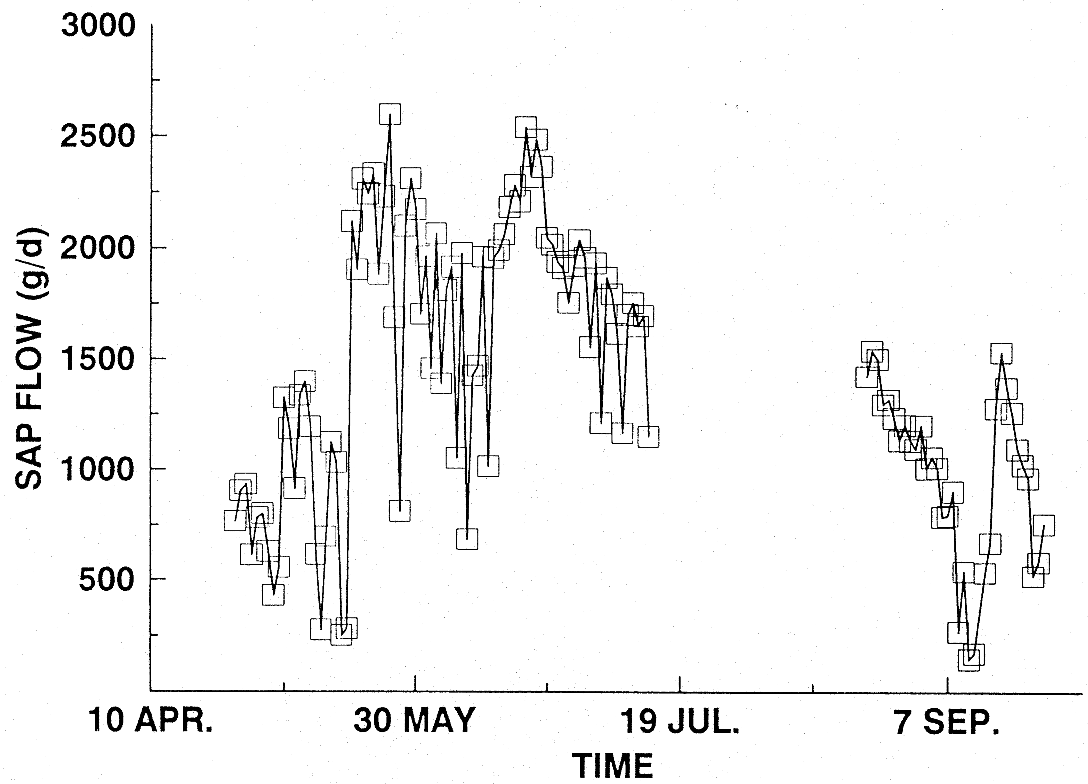

Fig. 8. Mean daylight mesquite sap flow from 9 stems in the untreated area in 1989.

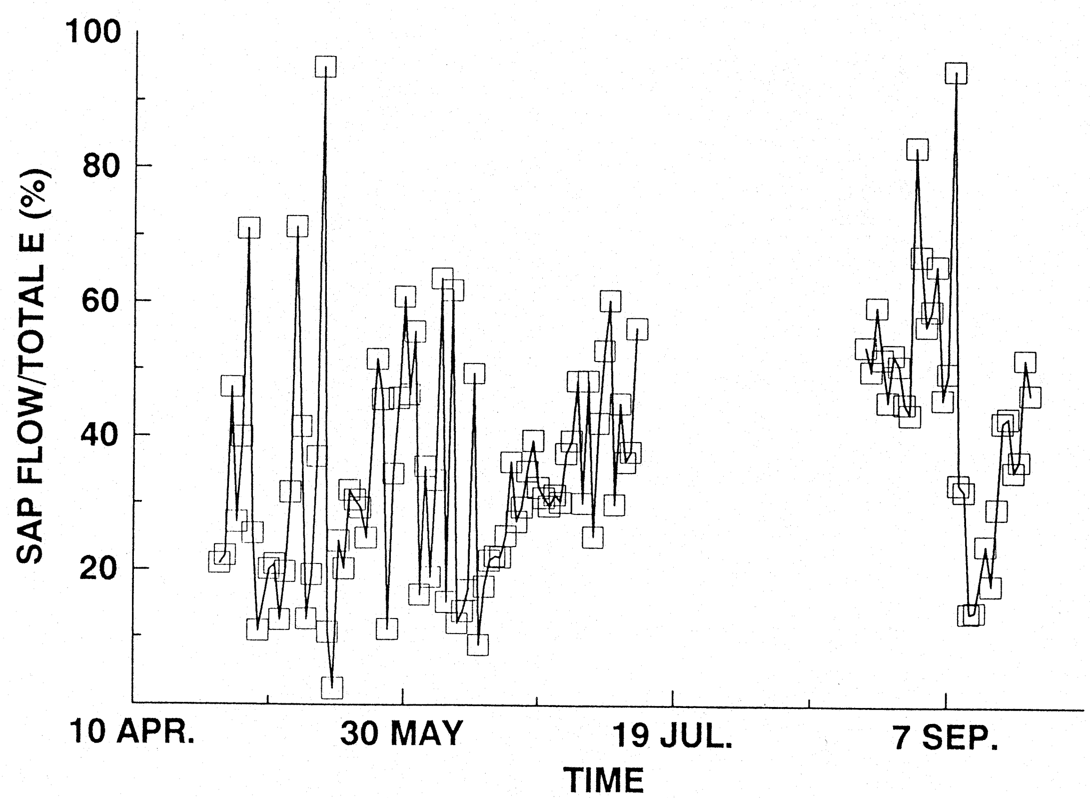

Fig. 9. Mean daylight honey mesquite sap flow expressed as percentage of the evaporation (E) from Bowen ratio instrumentation in the untreated area in 1989. A density of 4,000 stems ha^{-1} was used to convert the sap flow to daily rates of evaporation.

iately after precipitation, when soil water availability was high.

While honey mesquite used substantial amounts of water and increased E, the E from the rangeland without it was just slightly lower than E from a rangeland with it due to an increase in herbaceous E associated with increased standing crop following mesquite control. In this environment, which had a low potential for runoff and deep percolation, removal of honey mesquite would not be expected to increase availability of water for off-site uses because water not transpired by mesquite in subsequent years would be utilized by grasses. If so, brush control for purely hydrological purposes would not be justified. Increases in forage production following mesquite control equalling or exceeding those measured in this study have been reported at several locations in the same geographic area (Dahl et al. 1978, Jacoby et al. 1982, McDaniel et al. 1982, Bedunah and Sosebee 1984). However, differences in E or increases in off-site water availability as a result of honey mesquite control may occur under a grazing regime which precludes accumulation of additional herbaceous standing crop or for different soils.

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