SOIL MOISTURE USE BY VELVET MESQUITE

(*PROSOPIS JULIFLORA*)

by

Richard Christopher Martin

A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN WATERSHED MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

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SIGNED: Richard Christopher Martin

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Phil R. Ogden

PHIL R. OGDEN
Professor of Range Management

April 29, 1976
Date

ACKNOWLEDGMENTS

Never have I seen a day when Dr. Phil Ogden was too busy to help. My sincere thanks.

Thanks to Mr. Dwight Cable, particularly for assisting in all phases of the field work, and to Dr. David Thorud for serving on my committee.

Thanks also to Ann for everything, and to our constant companion, Heidi.

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ABSTRACT

The primary objective of this yearlong study was to determine the amount of soil moisture used by mature velvet mesquite (*Prosopis juliflora* var. *velutina*) trees on an upland site in southern Arizona.

Using the neutron thermalization method, soil moisture measurements were made adjacent to four live and four dead trees. Measurements were taken to a depth of 6 m and a distance of approximately 20 m from the trunks. Soil moisture levels at selected distances from the live and dead trees were compared and the differences graphically evaluated to determine seasonal soil moisture use.

Moisture use was plotted against distance from the trees. This distribution of use varied from season to season.

The maximum distance from the trees at which use was occurring fluctuated considerably from season to season but averaged approximately 20 m from the trunks. These fluctuations were attributed largely to the graphing technique.

The mean daily use of soil moisture for an average study tree was 468 l in the summer, 160 l in the fall, and 644 l in the spring. Assuming that use was insignificant during the winter dormancy period, the mean daily use for the entire study year was 322 l.

INTRODUCTION

The primary objective of this yearlong study was to determine the amount of soil moisture used by mature velvet mesquite (*Prosopis juliflora* var. *velutina*) trees on an upland site in southern Arizona. In addition, the moisture used by the trees at various distances from their trunks was quantified.

REVIEW OF LITERATURE

Even though various aspects of mesquite have been studied in detail (Schuster, 1969), little research has been aimed at quantifying the moisture used by these plants.

Soil Moisture Studies

Several investigators have studied the affect that mesquite trees have on soil moisture conditions. Usually, this involves a comparison of soil moisture values near live mesquite trees with those obtained in an area where the trees have been killed. Assuming all site conditions are uniform, these comparisons should give some indication of the location and magnitude of moisture used by the live trees.

Martin (1947) studied differences in soil moisture content between live and dead velvet mesquite trees from the surface to a depth of 46 cm at distances of 3.0, 6.1, and 9.1 m from the tree trunks. At 3.0 and 6.1 m from the dead trees, soil moisture was greater at all depths than at corresponding distances from the live trees. At 9.1 m from the trees: (1) There were no significant differences in soil moisture content between live and dead trees in the upper 30 cm of the profile, and (2) the moisture content under the dead trees was greater than under the live trees in the 30 to 46 cm soil layer. From these results, Parker and Martin (1952) later concluded that "velvet mesquite adversely influences soil moisture to a distance of at least 30 feet (9.1 m) from the plant."

Tiedemann (1970) conducted a similar study using velvet mesquite in southern Arizona. Soil moisture content was measured from the surface to a depth of 142 cm at 1.4 and 6.1 m from the trunks of both live and dead trees. At 1.4 m from the trunks: (1) The moisture content adjacent to the dead trees was greater than it was adjacent to the live trees in the upper 5 cm of soil, and (2) there were no significant differences in soil moisture content between live and dead trees from a depth of 30 to 142 cm. At 6.1 m from the tree trunks, no significant differences in soil moisture content were evident at any sampling depth. Thus, the only indication of any moisture use was at 1.4 m from the tree trunks. This appears to contradict Martin's (1947) work which was conducted on a similar site at the Santa Rita Experimental Range.

Hughes (1966) compared soil moisture values between an untreated honey mesquite (_P. juliflora_ var. _glandulosa_) stand, a root plowed area that apparently contained no mesquite, and a pasture in which 46% of the trees had been killed with an herbicide spray. Soil moisture determinations were made immediately adjacent to and approximately 2.1 m from the trunks of live trees in the untreated and sprayed areas, and at random locations in the root plowed area. Moisture content was studied from the soil surface to a depth of 91 cm in all three areas. Results showed that the root plowed and sprayed areas had more moisture at all depths than did the untreated stand. The study also indicated that more soil moisture was present under the mesquite canopies than in the open areas between trees. This is contrary to the results obtained by Martin (1947) which showed a tendency for soil moisture storage to become greater with increasing distance from live trees.

The research to date presents conflicting evidence. At least some of these contradictions could be explained by the understory vegetation present on all of the study sites. Various investigators have shown that the killing of mesquite substantially increases the herbage production of adjacent understory vegetation. For instance, Parker and Martin (1952) found that the density and yield of perennial grasses on range where velvet mesquite had been controlled were double those on adjacent untreated range within three years after treatment. Similar responses were observed by Hughes (1966) and Wied (1967) during their studies of honey mesquite in Texas. The increase in understory vegetation following mesquite control can influence soil moisture supplies. As a result, site conditions near the live trees and in areas of mesquite control may not be the same. This complicates any comparisons and makes the evaluation of moisture use by the live trees very difficult.

Transpiration Studies

Approximately 95% of all the moisture absorbed by plants is lost through transpiration (Kramer, 1969). As such, a review of pertinent transpiration studies can provide estimates of the total volume of soil moisture used by mesquite trees under varying environmental conditions.

McGinnies and Arnold (1939) grew velvet mesquite trees sealed in 76 l cans which could be weighed periodically to determine water losses. Six plants grown in sourthern Arizona for 454 days each lost an average of 0.46 kg of water per day. As these plants were small, clipped periodically, and given a continuous supply of moisture, their transpiration rates would not reflect those of mature trees growing under natural conditions. The primary objective of their research was to determine the quantity of water plants require to produce a unit weight of dry matter, exclusive of roots. Results indicated that perennial grasses common to southern Arizona were approximately three times more efficient than velvet mesquite in utilizing moisture. These findings substantiate the work done as early as 1915 by Bakke, who noted that many desert plants including mesquite "do not show an economy of the water loss."

Studies involving root containers have several possible sources of error including: the limitations that tanks place on root growth, excessive soil heating through the containers, and waterlogged soil conditions due to inadequate drainage.

Cunningham et al. (1973) studied the transpiration rates of several phreatophypte species including screwbean (<u>Prosopis pubescens</u>) along the Rio Grande in southern New Mexico. Transpiration rates were determined <u>in situ</u> by enclosing intact branches and measuring the increase in water vapor concentration of the air in the enclosure. The average transpiration rate of screwbean for the growing season of April through September was estimated to be 0.7 g/cm^2 leaf surface area per day. As screwbean had an average leaf surface area of 3.1 m^2, water loss per plant was approximately 21.6 kg/day.

Transpiration rates determined with enclosure techniques may not reflect water losses under natural conditions due to the alterations of the environment surrounding the plant.

STUDY AREA DESCRIPTION

The study was conducted on the Santa Rita Experimental Range in southeastern Arizona. The site is located at an elevation of 1,240 m on a bajada composed of alluvium from the Santa Rita Mountains. Mean annual precipitation is estimated to be 39 cm with approximately 55% occurring as thunderstorms in July, August, and September. Most of the remaining moisture is produced by frontal storms which occur from November through March. During the study year from June 9, 1971 through June 7, 1972, 39.8 cm of precipitation were recorded at the site. The weekly precipitation totals during this year are shown in Fig. 1.

The soil is classified as a Comoro series, a member of the coarse-loamy, mixed, thermic family of Cumulic Haplustolls. Soil textures are predominately sandy loams and loamy sands from the surface to a depth of 2.4 m. Clay is encountered at the 2.4 m depth and extends downward for 2.3 m. From 4.7 to 6.0 m, the soil is again characterized by sandy loams and loamy sands. A complete description of the soil profile is included in Appendix A.

Velvet mesquite is the dominant overstory vegetation at the study site. The understory plants include: burroweed (*Haplopappus tenuisectus*), Rothrock grama (*Bouteloua rothrockii*), sixweeks needle grama (*B. aristidoides*), and sixweeks threeawn (*Aristida adscensionis*).

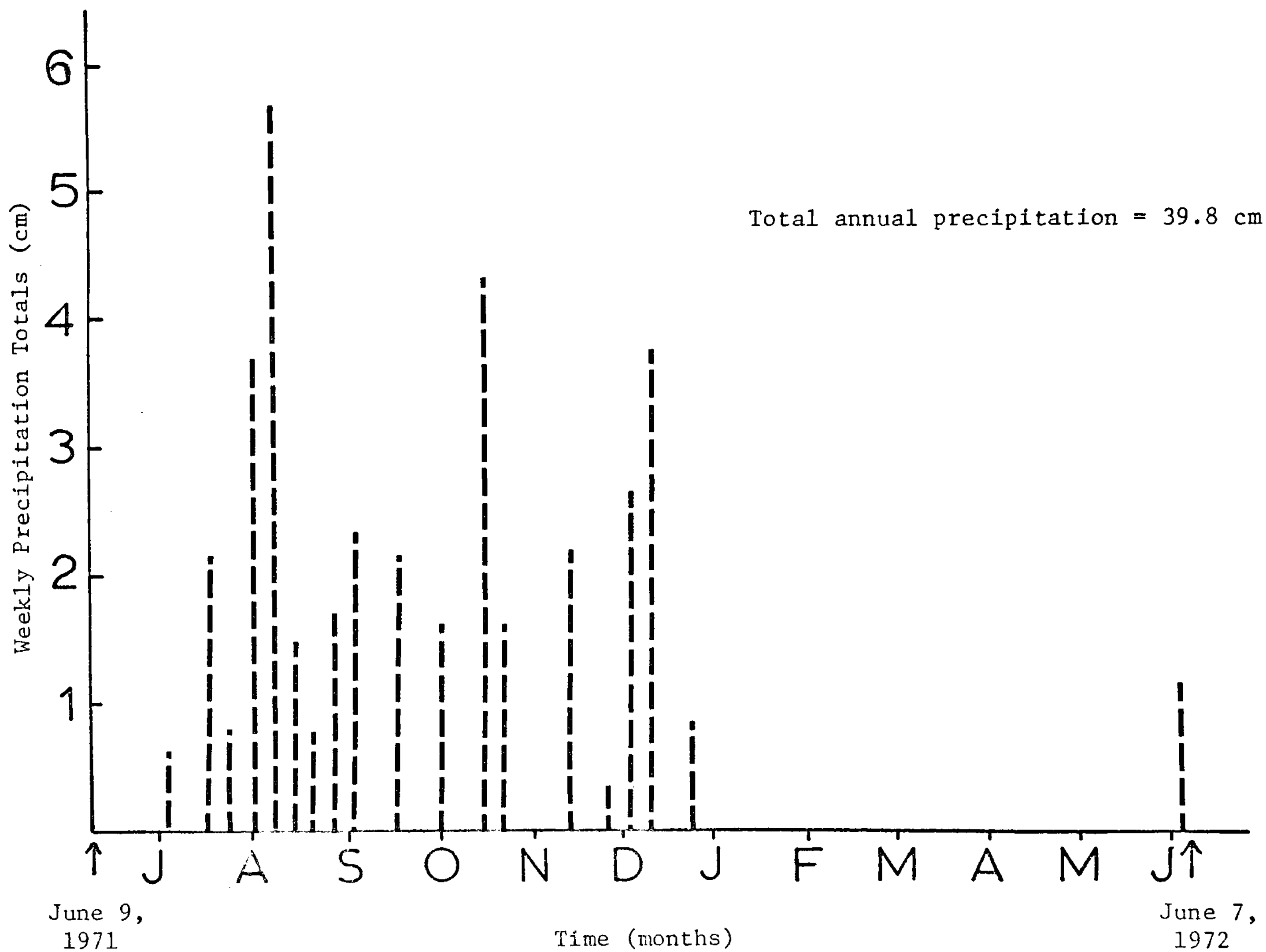

Fig. 1. Weekly precipitation at the study site from June 9, 1971 through June 7, 1972.

METHODS

A soil moisture measurement approach was utilized to quantity the amount of water used by mature velvet mesquite trees. As with other similar studies, soil moisture values adjacent to live trees were compared to those adjacent to recently killed trees. The relative differences in soil moisture were then evaluated to determine the quantity of water used by the live study trees at various times of the year. The neutron thermalization method, being fast and nondestructive, was utilized to measure soil moisture content on a volumetric basis.

Field Methods

Eight mesquite trees were selected for study. All trees were mature, ranged in height from 4.6 to 5.8 m, and appeared typical of the stand (Fig. 2). Four of these eight trees were randomly selected and killed with diesel oil.

A radial extending outward from each of the eight trees into adjacent openings was selected. Neutron probe access holes were installed along these radials with a rotary pneumatic well drilling rig. All holes were bored vertically to a depth of 6 m and cased with 5.1 cm OD aluminum irrigation tubing. Each of the four live study trees had a total of six access holes. Three holes were drilled under the canopy: one as close to the trunk as possible, one midway between the trunk and the edge of the tree canopy, and one at the edge of the canopy (Fig. 3). The remining three holes were drilled at 5, 10, and 15 m beyond the edge

Fig. 2. One of the mesquite trees selected for study.

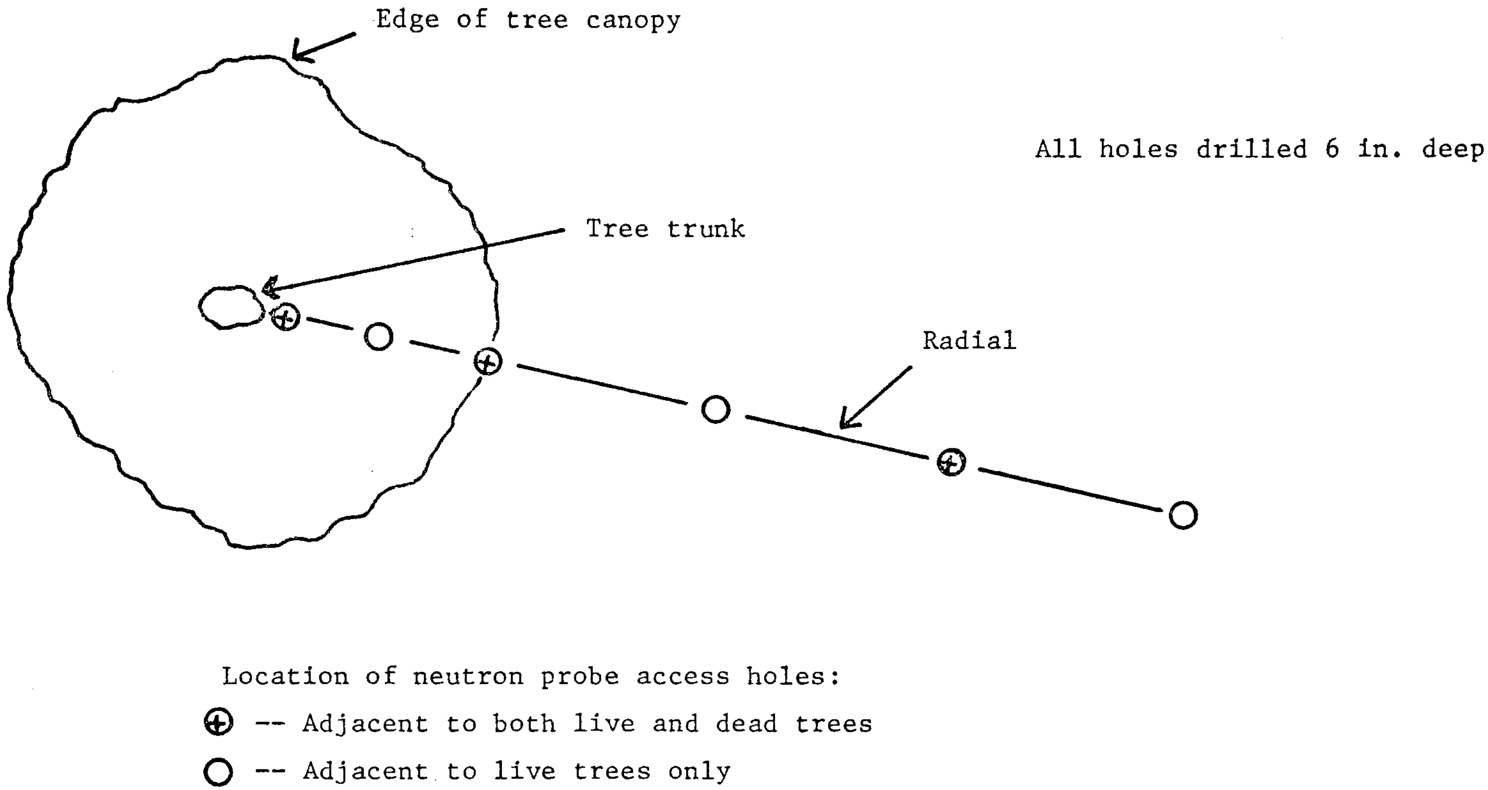

Fig. 3. A diagram showing the location of neutron probe access holes.

of the canopy along the radial. Each of the four dead study trees had three access holes: one as close to the trunk as possible, one at the edge of the tree canopy, and one 10 m beyond theedge of the canopy along the radial.

With the exception of the four live study trees, all vegetation near the radials was killed. Mesquite and other woody plants were killed with diesel oil. Bromacil was used to kill herbaceous vegetation adjacent to dead tree radials, and Paraquat was utilized along live tree radials.

A Troxler depth-moisture probe and scaler were utilized to make all soil moisture determinations; the source of fast neutrons being an Am-Be pellet. Soil moisture content was measured in each access hole at 13 different depths ranging from 25 cm to 6 m below the soil surface. Measurements were made at 25 cm intervals from the 25 cm to 2 m depth; 50 cm intervals from the 2 to 3 m depth; and 1 m intervals from the 3 to 6 m depth.

Soil moisture content was measured in all 36 probe access holes on 43 different occasions throughout the year. Due to the stability of soil moisture in the lower levels of the profile, data were not always collected at the 4, 5, and 6 m depths.

Data Analysis Methods

Only three live and three dead trees were utilized in the final analysis as: (1) A poorly installed neutron probe access tube adjacent to a dead study tree permitted soil moisture to flow down the outside of the pipe, and (2) one of thelive study trees never fully recovered from an insect attack which occurred in the spring of 1972.

The first phase of the analysis was to determine seasonal changes in soil moisture storage occurring at different distances from the live and dead trees. Five sampling dates which roughly coincide with the beginning and end of the four major seasons of the year were selected for detailed graphical analysis.

For each season, nine graphs, such as the one shown in Fig. 4, were constructed. Each of these graphs represented averages for three trees and denotes changes in soil moisture storage occurring at one of the six different sampling distances from the live tree truns or one of the three different sampling distances from the dead tree trunks.

On each graph, soil moisture contents at the beginning of a season were plotted against depth below the soil surface. A smooth continuous curve was then drawn between these points. This curve represented the average soil moisture conditions adjacent to the three live or three dead trees from the soil surface to a depth of 6 m. A similar soil moisture profile curve reflecting conditions at the end of the season was drawn on the same graph.

The hatched area in Fig. 4 represents the average change in soil moisture storage adjacent to the three live or three dead trees during the season of study. This area, bounded by the two soil moisture profile curves and by the soil surface and the 6 m depth, can be defined mathematically by the equation:

$$\overline{\Delta w} = \int_{t=1}^{2} \int_{z=o}^{600} \frac{\partial \theta}{\partial t}\, dzdt$$

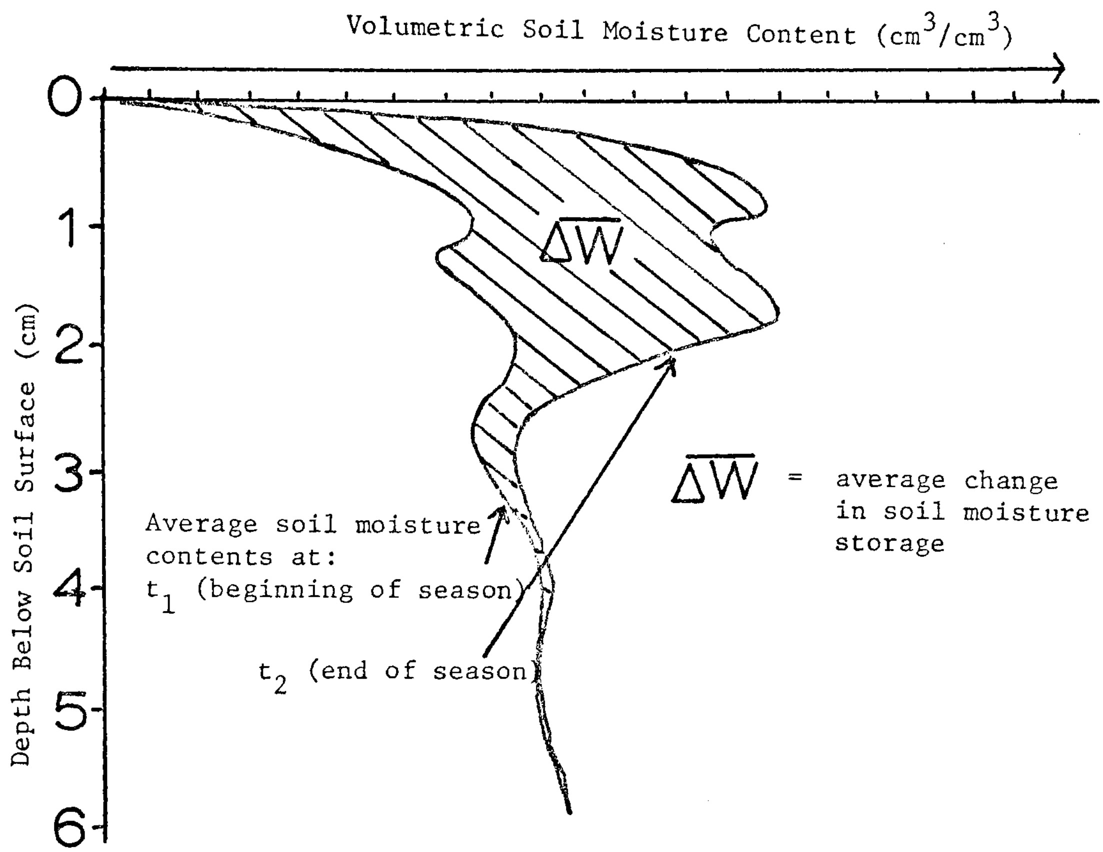

Fig. 4. Example of graph used to determine seasonal changes in soil moisture storage at different distances from the line and dead tree trunks.

where: $\overline{\Delta w}$ = average change in soil moisture storage (cm),

$t_2 - t_1$ = time period between the beginning and end of the season (days),

z = depth below the soil surface (cm), and

θ = volumetric soil moisture content (cm^3/cm^3).

The $\overline{\Delta w}$ was determined directly by planimetering the hatched area on the graphs. This phase of the analysis resulted in nine $\overline{\Delta w}$ values for each of the four seasons of study.

The second phase of the analysis was to determine seasonal soil moisture use by the live trees at various distances from their trunks. A graphing technique (Fig. 5) was utilized to compare $\overline{\Delta w}$ near the live trees with $\overline{\Delta w}$ near the dead trees. For each season, the six $\overline{\Delta w}$ values reflecting conditions near the live trees were plotted against distance from their trunks. A smooth continuous curve was then drawn between these points. On the same graph, another curve was fitted to the three $\overline{\Delta w}$ values which reflected conditions near the dead trees during this season. It was assumed that soil moisture use by the live trees was occurring at any distance from the trunks where: (1) The average gain in soil moisture storage near the dead trees was greater than it was near the live trees, or (2) the average loss in soil moisture storage near the dead trees was less than it was near the live trees. By comparing the two curves, such as those in Fig. 5, the magnitude of use at various distances from the trunks could be determined. For each study season, moisture use was then graphed as a function of distance from the trunks.

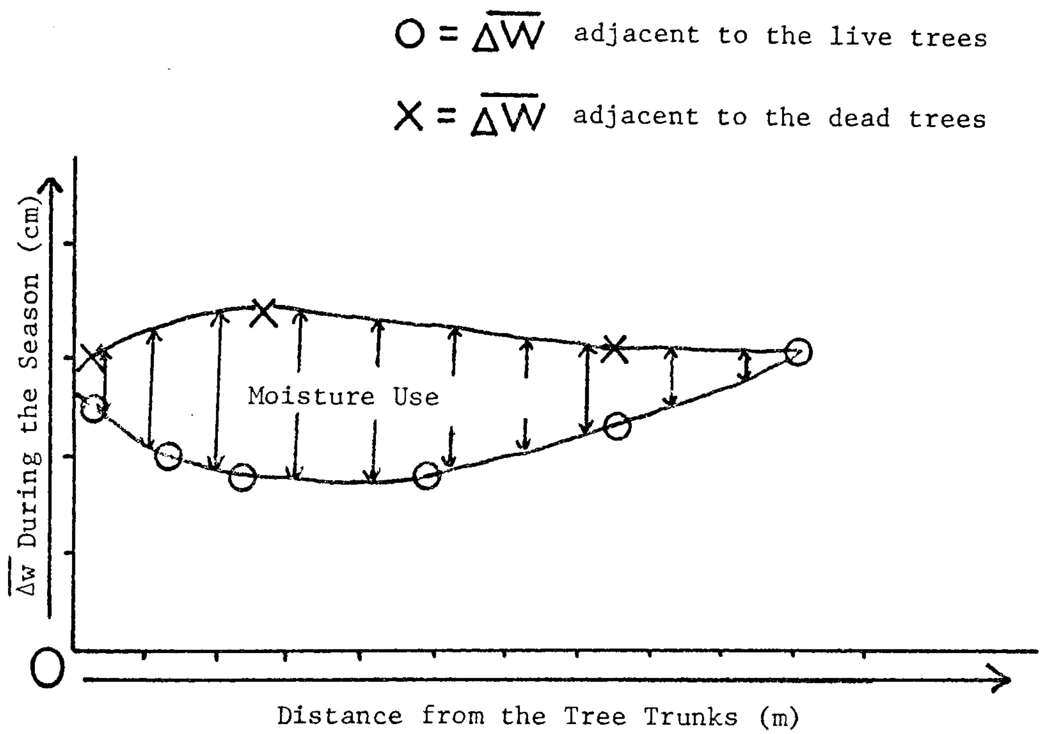

Fig. 5. Example of graph used to determine seasonal soil moisture use at various distances from the tree trunks.

Finally, the total amount of moisture used by a mature velvet mesquite tree during each of the four seasons was determined. Assuming that the moisture use along the sampling radial is representative of use around the entire perimeter of the tree, the total use can be calculated as follows:

$$\text{use} = 2\,\pi \int_{r=1}^{m} f(r)r\,dr$$

where: use = total amount of soil moisture used by an average study tree (cm^3),

f(r) = average moisture use by the study trees at various distances from their trunks (cm), and

r = horizontal distance from the tree trunk (cm).

The moisture used at various distances from the tree trunks [f(r)] was previously determined during the second phase of this analysis. The integ~~er~~ral was solved graphically by plotting [f(r)](r) against r and planimetering the area thus defined. This procedure resulted in a value for the total amount of soil moisture used by an average mesquite tree for each of the four study seasons.

RESULTS AND DISCUSSION

Soil Moisture Use at Various Distances from the Tree Trunks

Fig. 6 shows the average soil moisture use by the mature velvet mesquite trees at various distances from their trunks between June 9 and September 13, 1971. In spite of an ample supply of soil moisture, use near the trunks was negligible. With increasing distance from the trunks, use increased rapidly to a maximum of 7.4 cm near the edge of the canopies and then steadily decreased. The graphing technique indicated that the trees were capable of utilizing moisture to a distance of approximately 22 m. This is possible as Cannon (1925) observed velvet mesquite with lateral root growth of 25 m or more.

Fig. 7 illustrates the distribution of moisture use along the radials between September 14 and November 29, 1971. As might be expected, use was generally much less than during the summer months, reaching a maximum of only 4.2 cm. This could be attributed to the shorter study season, depleted soil moisture supplies, and the reduced transpiration rates associated with the cooler fall air temperatures.

Unlike the preceding summer season, the trees appeared to be using moisture immediately adjacent to their trunks. This could have been the result of lateral movement of soil moisture away from the trunks rather than actual root absorption. By the end of November, soil moisture supplies approximately 1 to 7 m from the trunks were depleted below drought

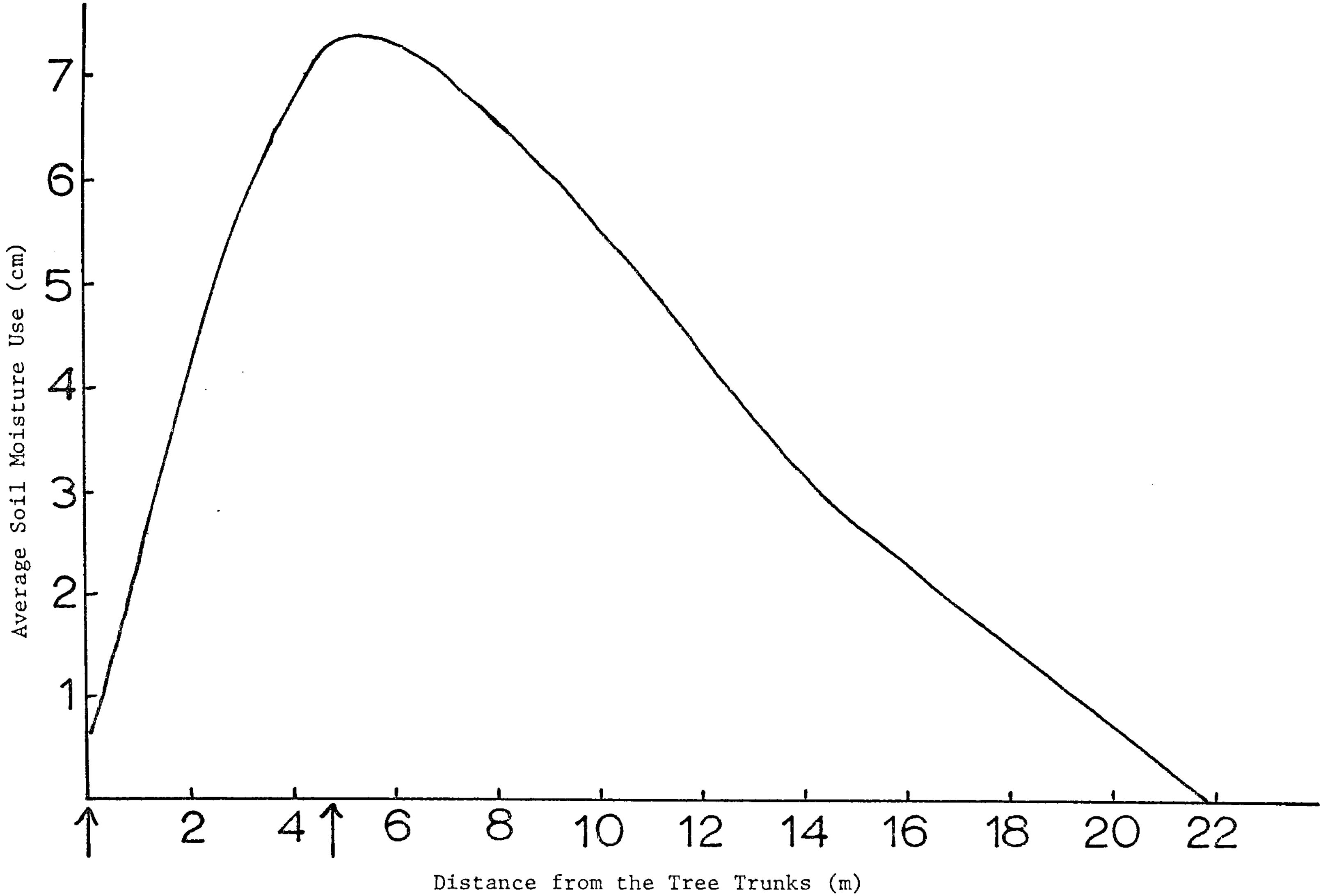

Fig. 6. Average soil moisture use by the mesquite trees at various distances from their trunks between June 9 and September 13, 1971.

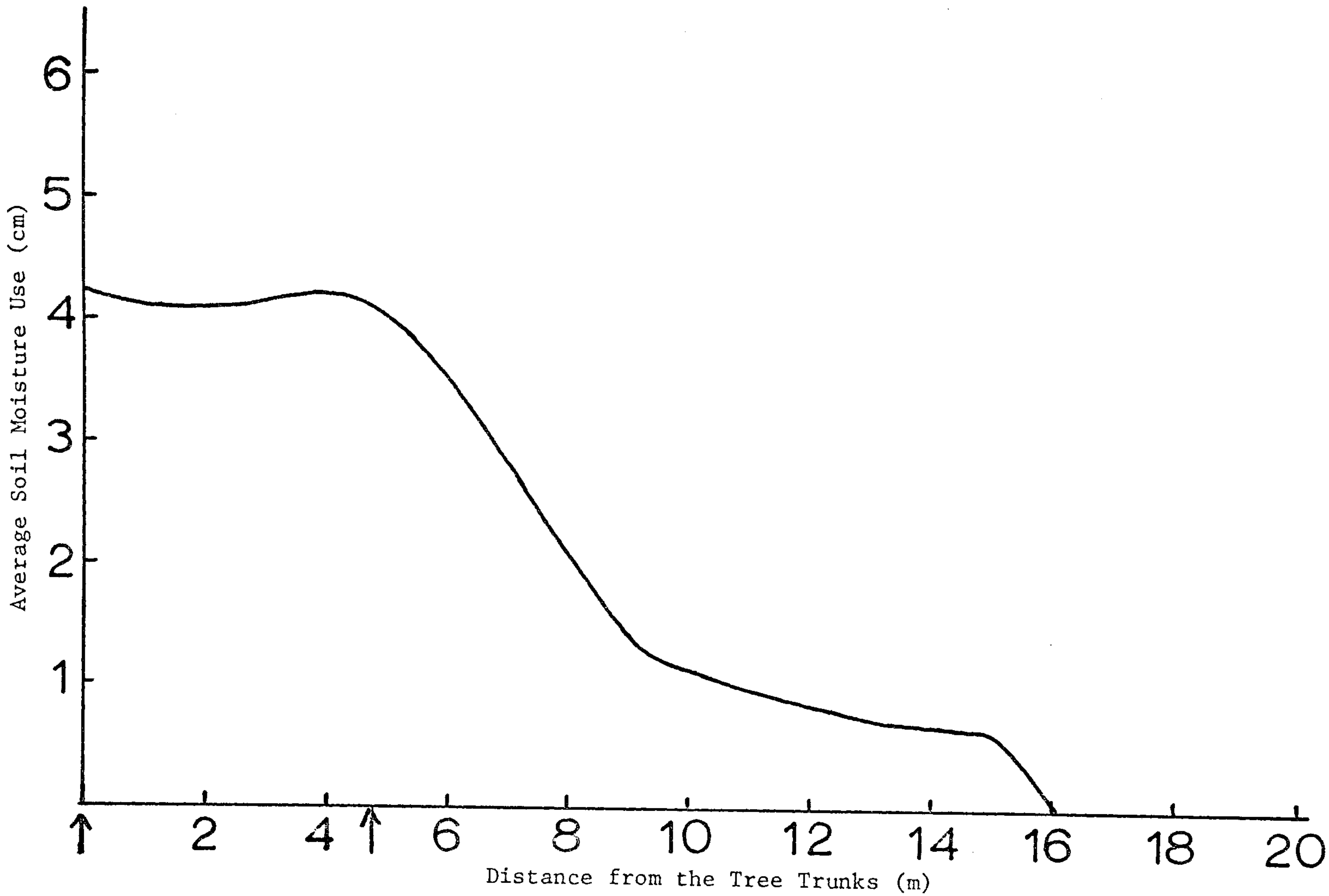

Fig. 7. Average soil moisture use by the mesquite trees at various distances from their trunks between September 14 and November 29, 1971.

levels that existed during June of 1971. This extremely dry profile would have facilitated the movement of moisture away from the trees.

The maximum distance of moisture use appeared to be 16 m from the tree trunsk, 6 m less than during the previous summer season. This could have been more a result of the graphing technique than an actual change in use patterns. In one instance, a change in total moisture storage of only 1 cm at 20 m from the trunks could vary the maximum distance of use as shown on the graphs by more than 7 m.

The trees were dormant from approximately November 30, 1971 through March 6, 1972. During this period, the soil adjacent to the live trees gained much more moisture than the soil under the dead trees, making it impossible to detect any use. Some moisture could have been absorbed to replace lenticular transpiration losses and to enable various metabolic processes, but such use probably would be negligible during dormancy. The greater increase in soil moisture content adjacent to the live trees as compared to the dead trees could be attributed to the saturated soil conditions that existed under the dead trees during December. These moist conditions probably reduced infiltration rates which, in turn, increased surface runoff. In addition, the moist soil would tend to increase evaporative losses near the dead trees, accentuating the relative gain in soil moisture under the live trees. The greater runoff and evaporative losses occurring on the soil without plant growth indicates the important role of vegetation in holding moisture on site.

Unusually dry conditions prevailed from January until early June. As a result, soil moisture supplies were significantly depleted during the spring growing season of March 7 through June 7, 1972.

It appears from Fig. 8 that moisture use under the tree canopies was minimal. It is possible, however, that water from the moist soil adjacent to the dead trees continued to evaporate after all the available moisture near the live trees had been utilized. These greater evaporative losses would tend to minimize any differences in seasonal soil moisture storage changes. Thus, what appears as lack of moisture use by the live trees could in reality be a result of differences in evaporative losses.

The greatest moisture use occurred between 9 and 16 m from the trunks. This was considerably further from the trees than in previous seasons and may have been due to the limited soil moisture supplies near the canopies.

The maximum distance of tree use as defined by the graphing technique was 33 m from the trunks. This was a large increase over previous seasons and may have resulted from the germination of spring annuals along the live trees radials. These annuals concentrated near the outermost neutron probe access holes and undoubtedly used some soil moisture prior to being killed. This use would tend to reduce soil moisture contents and lengthen the maximum distance of tree use as shown on the graphs. Other possible causes of this large increase in distance would include lateral soil moisture movement, differential rates of evaporation, and the sensitive graphing technique.

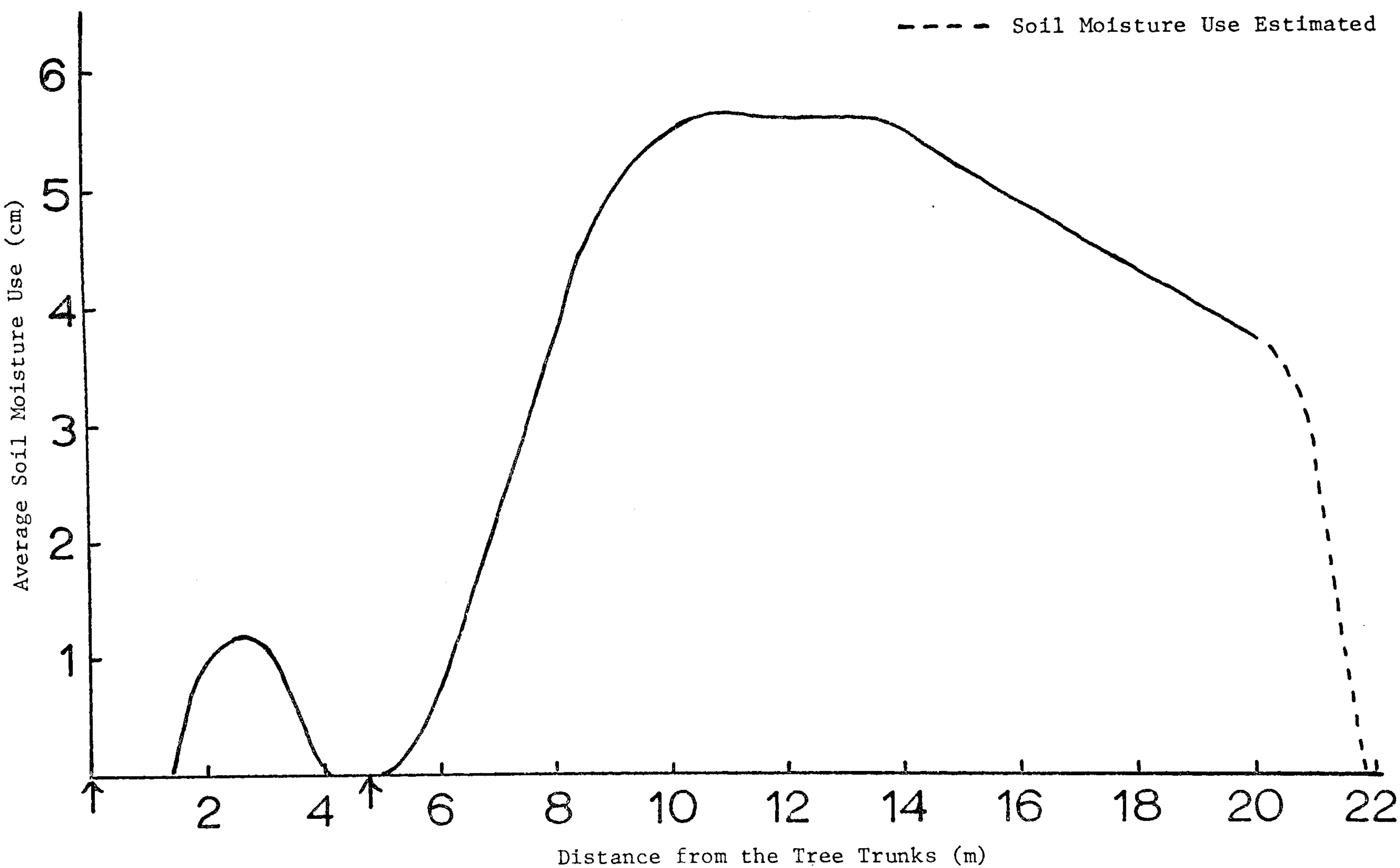

Fig. 8. Average soil moisture use by the mesquite trees at various distances from their trunks between March 6 and June 7, 1972.

In light of these problems, it was assumed that the actual point of maximum use was 22 m from the trunks. This point was selected as it represented the maximum distance of use during the summer season. In addition, this is the maximum distance from the trunks where the live trees gained more moisture than the dead trees during the winter dormancy period. This implies that moisture use had been occurring primarily within this 22 m distance.

The average soil moisture use at various distances from the trunks during the summer, fall, and spring seasons were totaled and graphed (Fig. 9). As tree use during the winter dormancy period was probably negligible, the curve should approximate the distribution of use along the sampling radials for the entire study year beginning June 9, 1971 and ending June 7, 1972.

The comparative techniques utilized in this study to evaluate soil moisture absorption assume that all abiotic environmental conditions are uniform throughout the study area. As soon as the control trees are killed, however, this assumption is no longer completely valid. As use of water by the dead trees is nonexistent, soil moisture storage tends to increase. The greater soil moisture under the dead trees reduces infiltration rates, increases evaporative losses, and facilitates moisture movement to drier portions of the profile. These factors tend to reduce any differences in seasonal changes in soil moisture storage that may exist between live and dead trees as a result of use. The smaller differences in seasonal soil moisture storage changes, in turn, cause use by the live trees to be underestimated.

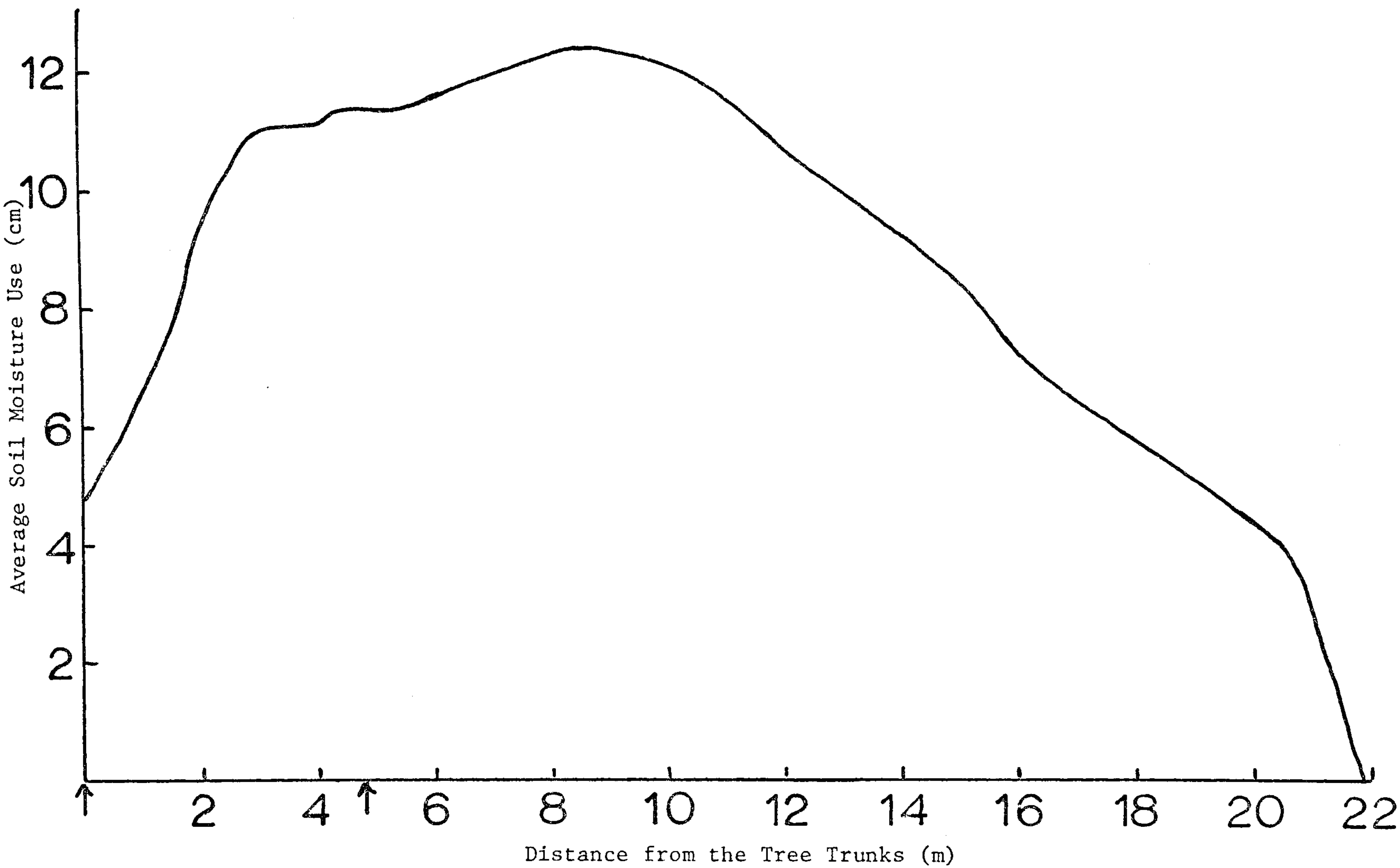

Fig. 9. Average soil moisture use by the mesquite trees at various distances from their trunks during all of the summer, fall, and spring seasons.

In addition, this method assumes that the live and dead trees are similar except for their ability to absorb soil moisture. This is not the case, however, as the foliage present on the live trees during much of the year is absent from the dead trees. This difference in foliage could affect soil evaporation and interception losses. Tiedemann (1970) calculated potential evaporation to be twice as great in the open as in the shade of a mesquite tree. However, Shreve (1931) indicated that the actual evaporation rates in the sun and the shade of *Parkinsonia* (a tree similar to mesquite) were not significantly different. Any increase in evaporation under the dead trees may have been partially offset during periods of rain and snowfall when the live trees would have greater interception losses.

Total Amount of Soil Moisture Use

The total amount of soil moisture used by an average study tree as well as the mean daily use during each of the season are listed in Table 1.

The mean daily use of 468 l during the summer season would have been much greater if the soil profile had not been extremely dry prior to the summer rainy season. During the fall, the mean daily use declined to 160 l. This could be attributed primarily to the cooler air temperatures and resultant decrease in transpiration rates. As the soil under the live trees gained more moisture than the soil under the dead trees, no use could be detected during the winter dormancy period. The mean daily use of 644 l during the spring was greater than for any other season.

Table 1. The total amount of soil moisture used by an average study tree and the mean daily use during each of the study seasons.

Study Season	Total Volume of Use (l)	Length of Season (days)	Mean Daily Use (l)
6/9/71 through 9/13/71	45,400	97	468
9/14/71 through 11/29/71	12,300	77	160
11/30/71 through 3/6/72	a	98	a
3/7/72 through 6/7/72	59,900	93	644
6/9/71 through 6/7/72	117,600	365	322

a. Use during the winter dormancy period was assumed to be insignificant.

This was mainly a result of large transpiration losses associated with warm daytime air temperatures and ample soil moisture supplies.

During a year of nearly average precipitation, a mature velvet mesquite tree used approximately 117,600 l of water or 23% of the precipitation that fell during the study year. In the desert grassland, it takes approximately 0.48 l of water to produce 1 g of air dried grass, exclusive of roots (McGinnies and Arnold, 1939). Consequently, each mesquite tree used enough water to produce 248 kg of air dried herbage.

The amount of soil moisture used by vegetation is normally expressed in terms of leaf surface area. As such, calculating the leaf surface area of the study trees would have facilitated the comparison of soil moisture use rates with those obtained in other studies.

It should be realized that these trees were isolated from other plants that under more natural conditions would have used a significant amount of soil moisture. As such, the total quantity of moisture used by the mesquite trees probably would have been somewhat less in an undisturbed plant community.

CONCLUSIONS

1. Use at various distances from the trunks during the entire study year was estimated by totaling use during the summer, fall, and spring seasons. During this period, use immediately adjacent to the trunks was moderate. With increasing distance from the trunks, use increased rapidly to a distance of 3 m, was the greatest between 3 and 12 m, and then decreased at a relatively steady rate until no use was evident.

2. During any one season, the quantity of soil moisture used by mesquite varied with distance from the trunk. This variation or distribution of use along the radials was not, however, consistent from season to season. As a result, no general conclusions concerning use at various distances from the trunks could be reached that would apply to all seasons of the year.

3. The maximum distance from the trees at which use was occurring fluctuated considerably from season to season but averaged approximately 20 m from the trunks. These fluctuations could be attributed largely to the graphing technique.

4. The mean daily use of soil moisture for an average study tree was 468 l in the summer, 160 l in the fall, and 644 l in the spring. Assuming that use was insignificant during the winter dormancy period, the mean daily use for the entire year was 322 l.

5. During the study year, soil moisture storage adjacent to the dead trees was generally greater than it was adjacent to the live trees. This greater soil moisture probably increased surface runoff and

evaporative losses near the dead trees which would have caused soil moisture use by the live trees to be underestimated.

6. If the trees had not been isolated from other plants in the community, they probably would have used less soil moisture.

7. Despite the many problems encountered, this method offers a means of determining the quantity of moisture used by plants without significantly altering their immediate environment.

APPENDIX A

SOIL PROFILE DESCRIPTION[a]

Horizon	Depth Below Soil Surface (inches)	Description
A11	0-3	Brown (10YR 5/3) gravelly sandy loam, dark brown (10YR 3/3) moist; weak fine and medium granular structure breaking to massive (structureless); slightly hard, very friable, nonsticky and nonplastic; 30% gravel; common very fine and fine roots; common very fine interstitial pores; noneffervescent; slightly acid (pH 6.5); clear wavy boundary.
A12	3-14	Brown (10YR 4/3) gravelly sandy loam, dark brown (10YR 3/3) moist; structureless, massive; soft, very friable, nonsticky and nonplastic; 15% fine gravel; few very fine and fine roots; common very fine interstitial and few fine tubular pores; neutral (pH 6.8); clear wavy boundary.
A13	14-25	Brown (10YR 5/3) sandy loam, dark brown (5YR 3/3) moist; structureless, massive; soft, very friable, nonsticky and nonplastic; 10% fine gravel; few very fine, fine, and medium roots; common very fine interstitial and few fine tubular pores; neutral (pH 6.8); clear wavy boundary.
IIC1	25-45	Dark yellowish brown (10YR 4/4) very gravelly sandy loam, dark yellowish brown (10YR 3/4) moist; structureless, massive; 80% fine gravel; few very fine roots; common fine interstitial and few fine tubular pores; neutral (pH 6.8); clear wavy boundary.
IIC2	45-80	Dark yellowish brown (10YR 4/4) very gravelly loamy sand, dark brown (7.5YR 4/4) moist; structureless, massive; slightly hard, very friable, nonsticky and nonplastic; 75% fine gravel, 5% coarse gravel and 5% cobble; common fine and

Horizon	Depth Below Soil Surface (inches)	Description
		few fine tubular pores; neutral (pH 7.0); abrupt wavy boundary.
IIC3	80-93	Reddish yellow (5YR 6/6) very gravelly loamy sand, yellowish red (5YR 4/6) moist; structureless, massive; very hard, very friable, nonsticky and nonplastic; 85% fine gravel; very few thin clay films on sand grains; neutral (pH 7.0); clear wavy boundary.
IIIB2tb	93-97	Reddish brown (5YR 4/4) very gravelly clay, reddish brown (5YR 4/4) moist; structureless, massive; hard, friable, slightly sticky and nonplastic; 90% fine gravel; common moderately thick clay films on gravel; neutral (pH 7.0); abrupt wavy boundary.
IIIB3b	97-106	Red (2.5YR 4/6) very gravelly sand clay loam, red (2.5YR 4/6) moist; structureless, massive; hard friable, slightly sticky and nonplastic; 50% gravel; neutral (pH 7.0); clear wavy boundary.
IVB2tb	106-113	Reddish brown (2.5YR 4/4) very gravelly clay, reddish brown (2.5YR 4/4) moist; structureless, massive; very hard, friable, sticky and nonplastic; few thin clay films on gravel; 50% fine gravel and 45% coarse gravel; mildly alkaline (pH 7.5); abrupt wavy boundary.
IVB3b	113-135	Yellowish red (5YR 5/6) very gravelly sandy clay loam, reddish yellow (5YR 6/6) moist; structureless, massive; 45% fine gravel and 10% coarse gravel; neutral (pH 7.0); clear wavy boundary.
VB2b	135-183	Yellowish red (5YR 5/6) very gravelly sandy clay, reddish yellow (5YR 6/6) moist; structureless, massive; hard, friable, slightly sticky and nonplastic; 75% fine gravel and 10% coarse gravel; mildly alkaline (pH 7.5); clear wavy boundary.
VIC1	183-211	Yellowish red (5YR 4/8) very gravelly loamy sand, yellowish red (5YR 4/8) moist; structureless, massive; slightly hard, very friable, nonsticky and nonplastic; 85% fine gravel and

Horizon	Depth Below Soil Surface (inches)	Description
		5% coarse gravel; mildly alkaline (pH 7.5); clear wavy boundary.
VIC2	211-227	Yellowish red (5YR 5/6) gravelly loamy sand, yellowish red (5YR 4/6) moist; structureless, massive; slightly hard, very friable, nonsticky and nonplastic; 20% fine gravel and 5% coarse gravel; neutral (pH 6.8); clear wavy boundary.
VIC3	227-237	Strong brown (7.5YR 5/6) gravelly sandy loam, strong brown (7.5YR 5/6) moist; structureless, massive; hard, very friable, nonsticky and nonplastic; 15% fine gravel; neutral (pH 7.0); clear wavy boundary.
VIC4	237-242+	Strong brown (7.5YR 5/6) very gravelly loamy sand, strong brown (7.5YR 5/6) moist; structureless, massive; loose and incoherent, very friable, nonsticky and nonplastic; 70% fine gravel; slightly acid (pH 6.5).

Although the Comoro series is usually more alkaline, the parent material in this area has come from noncalcareous sources. The soil appears to be within the range of characteristics. The small b in the horizon label indicates old buried material from previously eroded soils.

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a. Description by Stanley Clemmons, Soil Scientist, U. S. Forest Service.

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