EFFECT OF GOAT GRAZING, MECHANICAL SHRUB CLEARING AND EUCALYPT RINGBARKING ON RUNOFF AND SOIL WATER AVAILABILITY IN A WOODY SHRUB INVADED SEMI-ARID WOODLAND

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Abstract

Runoff and soil water have been measured on differently managed areas of shrub invaded semi-arid woodland near Coolabah, in north-western N.S.W. Measurements commenced in spring of 1975 and are continuing. Results to the end of 1976 are presented. With the exception of a very wet 10 day period in early 1976, when runoff results were lost, about 7% of rainfall ran off the mechanically shrub cleared country while 18% was similarly lost from the uncleared area. Runoff was much less from thicket areas than from the relatively more open inter-thickets. Some runoff from inter-thickets was shown to run on to, and to infiltrate the thicket soils. During an unusually wet period *c.*40% more soil water accumulated on the shrub-cleared country than on its exclosed or grazed counterparts, while a further 28% accumulated on that country where eucalypts were also ring-barked. Enhanced herbage production on the shrub cleared areas caused the extra accumulated soil water to be rapidly used following the onset of dry weather.

Introduction

Large areas of the originally open woodlands on the red soils in the eastern portion of the Western Lands Division of N.S.W. have been invaded by woody shrub species (Anon. 1969; Moore 1969, 1973).

Extensive sheet erosion of the bare areas between patches of woody shrubs is reputed to have occurred on undulating country. This suggests that a significant proportion of the rainfall incident on undulating country is lost as runoff. Measurements of runoff on undulating country at Cobar between May and November of 1968 showed that an average *c.*18% of the incident rainfall failed to infiltrate during that relatively short period (Anon. 1969). On the worst eroded country in the Cobar area it is considered by some that very little rainfall infiltrates into the eroded soils (Cunningham 1967). Cunningham (*loc. cit.*) states that on such country, most rain is lost as runoff to the flats where the combination of runon water and the seed it carries gives rise to a thick growth of seedlings of noxious scrub. At the same time, the resulting lack of seed, moisture and top-soil on the ridges makes colonization of bare areas very unlikely.

In such a semi-arid system it is most likely that there is strong competition between trees, shrubs and herbage for water. Consequently there is a need to study the utilization of water within the shrub invaded woodland and to quantify any effects that management manipulations may have on its availability. This need is highlighted by the fact that several of the management strategies actually recommended for this type of country (Anon. 1969) either depend on, or, will have a strong effect on the reallocation of water within the community. These proposed managements include ringbarking, clearing followed by the growing of a fodder crop, using water spreading techniques to develop the flat areas for fodder cropping and improved pastures (Cunningham 1975), and the contour furrowing of undulating country.

Consequently, a study was set up to a) document patterns of runoff and soil-water availability in a shrub invaded semi-arid woodland and b) quantify the effects of goat grazing, mechanical clearing of shrubs and ringbarking of *Eucalyptus populnea* (bimble or poplar box) on the above parameters.

Methods

The study is located on some of the differently treated areas which are part of a collaborative study by the CSIRO Division of Land Resources Management of the structure and functioning of, and the effect of perturbation on, a shrub invaded semi-arid woodland community near Coolabah in north-western N.S.W. (see also Harrington, this conference).

There are two replicates of the following four treatments

i) exclosed,
ii) goat grazed at 1 goat per 2 ha,
iii) shrub-cleared and goat grazed (1:2 ha), and
iv) eucalypt ringbarked, shrub-cleared and goat grazed (1:2 ha).

Shrub clearing was achieved by using a bulldozer to push out all shrubs and trees with a trunk diameter of less than 30 cm at a height of 1.5 m. Ringbarking was carried out by cutting deeply through the cambium of all trees left standing by the bulldozer. Deep ringbarking ensured loss of all leaf within 30 days. Eucalypt sucker regrowth is removed monthly. Treatments were applied during late summer of 1975.

A stratified sampling system for both runoff and soil-water was necessary to accommodate the strongly patterned vegetation distribution and microtopography of the area. The basic unit of vegetation pattern or "cell" (Harrington, unpublished data) is a mature eucalypt tree (usually *Eucalyptus populnea*) surrounded by a thicket of woody shrubs about 15 m in diameter, which is in turn surrounded by a sparsely vegetated inter-thicket area of usually between 20 and 50 m to the next thicket. The soil surface at the centre of the thicket areas are usually 20 cm above the average level of the surrounding inter-thicket, which in the area studied has an average slope of 1%.

In each of the four treatments in each replicate two representative cells were selected for study. Cells were selected on the basis of similar a) size of central eucalypt, b) thicket diameter, c) slope of inter-thicket area, d) position on the catena, e) depth to parent material and f) soil type.

Runoff is collected for measurement on only one of each of the two representative cells of each of the eight replicate-treatment combinations. A 22 cm galvanised iron strip is buried 10 cm into the soil to constrain the runoff from the thickets and also from the selected inter-thicket areas to flow into collecting troughs and thence into 1250 litre corrugated iron holding tanks set 60 cm into the ground. The average area of a thicket runoff plot is 100 m^2 while all inter-thicket runoff plots are 40 m^2. Thus the installations are capable of holding 12 and 31 mm of runoff respectively. When possible, the quantity of water in the tanks is measured and the tanks pumped out after each runoff event.

For soil water measurements a total of 15 neutron moisture meter (NMM) access tubes were installed in each cell, in three rows of 5 tubes each, radiating upslope, across the contour and downslope from the central eucalypt. The five access tubes in each row are located at i) 2 m from the eucalypt, ii) 5 m, iii) 10 m, iv) half way from the 10 m tube to the centre of the inter-thicket area and v) at the centre of the inter-thicket area. Thus a total of 240 tubes are monitored.

NMM access tubes were installed to bedrock in all cases. The rock was also drilled for a further 15 cm to allow the centre of activity of the NMM to be lowered to the bedrock level. Depth to bedrock was very variable, ranging from a minimum of 48 to a maximum of 118 cm. The average soil profile depth was 74 cm with 8% of soil profiles being shallower than 60 cm and another 8% deeper than 90 cm.

Readings were taken at approximately monthly intervals using a Wallingford NMM to count for 16 seconds at depths of 3 cm, 15 cm, and thence at 15 cm intervals, until the bottom of the hole was encountered, where a final reading was taken. As the meter is calibrated against the mean water content of 15 cm intervals (except for the 3 cm reading) it was thus possible to estimate soil water status to a depth of 75 mm below the surface of the bedrock. The NMM was successfully calibrated in the field for depths of 3, 15 and >30 cm. The proportion of variance of volumetric water content accounted for by the calibration regressions was 92, 97 and 83% respectively.

Results

During the period from the start of this study (1.9.75) to December 31, 1976, the total rainfall received at the site was 821 mm (Figure 1). This was almost double the expected value of *c*.445 mm (the median rainfall for the appropriate 16 month period at Byrock, some 25 km to the north of the experimental area, as calculated from Byrock median annual rainfall and adjusted for the extra period using Bourke consecutive month median information (Australian Water Resources Council 1968)). Of this rainfall, some 490 mm fell during the wet period of from early December 1975 to early March 1976, including 186 mm during the 9 day period of from February 23 to March 2, 1976.

Table 1. Rainfall and runoff from shrub cleared and undisturbed thicket and inter-thicket areas

Period	Rain (mm)	Runoff (mm)			
		Thicket		Inter-thicket	
		Cleared	Undist.	Cleared	Undist.
Sept. 1 to Nov. 30, 1975	103	1	1	4	11
Dec. 1, 1975 to Feb. 22, 1976	303	13	16	41	96
Feb. 23 to Mar. 2 (flood period)	186	?>12	?>12	?>31	?>31
Mar. 3 to May 31	10	0	0	0	0
Jun. 1 to Aug. 31	69	0	1	2	7
Sept. 1 to Nov. 30	116	0	1	2	13
Dec. 1 to 31, 1976	34	0	1	2	8
Total excl. flood period	635	14	20	51	135
Runoff as % of rainfall		2	3	8	21
Total incl. flood period	821	?>26	?>32	?>82	?>166

Table 2. Computed infiltration (mm) on Dec. 6, 1975 (Rainfall = 34 mm) for undisturbed areas without runoff plots

Transect	Distance from tree (metres)						
	2	5	10	18	27	L.S.D.(0.05) between distances	Mean
Upslope	39	32	25	12	13		24
Contour	32	27	20	15	12	8	21
Downslope	29	25	17	12	10		19
L.S.D. between (0.05) directions			7				3
Mean	33	28	21	13	12	5	21

Unfortunately, the flooding produced by the rainfall of Feb. 23 - Mar. 2 prevented personnel from reaching the site to measure and empty the runoff tanks. As all tanks overflowed, the only information available for this period is that runoff exceeded 12 mm on the thicket areas and 31 mm on the inter-thicket areas (Table 1). Apart from this unusual event, the percentage of total rainfall (635 mm) that was collected as runoff has been surprisingly low - 3% and 21% from undisturbed thickets and inter-thickets respectively and 2% and 8% for their disturbed counterparts.

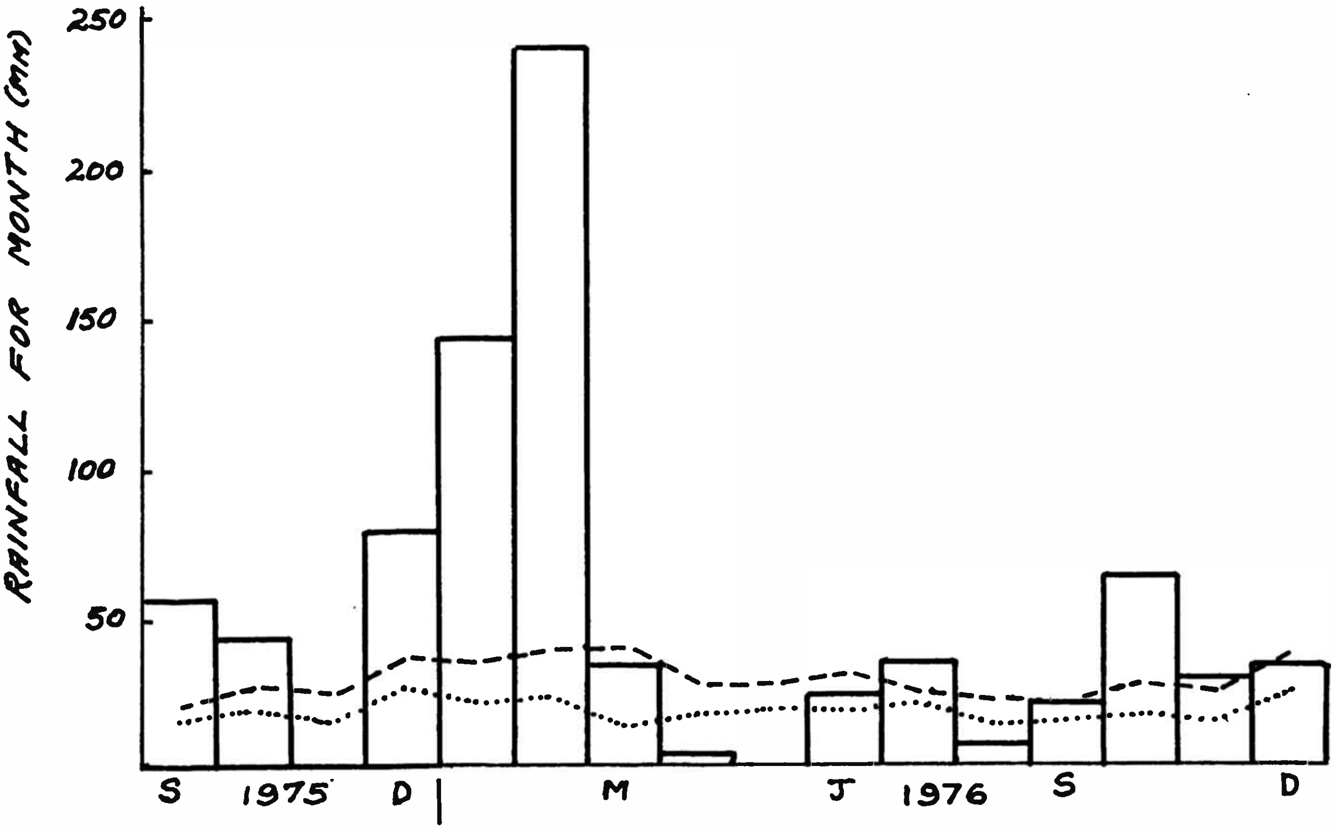

Figure 1. Monthly rainfall recorded at Coolabah site, and monthly means (----) and median (·····) for Byrock (70 year period).

Runoff percentages from individual storms were, of course, much greater than the above averages. On December 6, 1975, 34 mm of rain was recorded in just over two hours, with 28 mm falling during the first 40 minutes. During this storm undisturbed inter-thicket areas yielded up to 83% runoff, with an average yield of 63% while disturbed inter-thickets averaged 36%. In contrast, thicket counterparts yielded only 16% and 14% respectively.

As can be inferred from Table 1, many rainfall events produce negligible thicket runoff. During such events some of the runoff produced by inter-thicket areas has been found to run into the thickets where part of it augments the soil water status on the upslope side of the eucalypt. NMM measurements carried out three days after the storm of Dec. 6, 1975 showed that extremes of up to 90 mm infiltrated at some sites near the centre of thickets. Computed average infiltrations (mm) for undisturbed areas without runoff installations on Dec. 6 range from up to 5 mm in excess of the rainfall amount at 2 m upslope from the tree (Table 2) to 24 mm less at 27 m downslope.

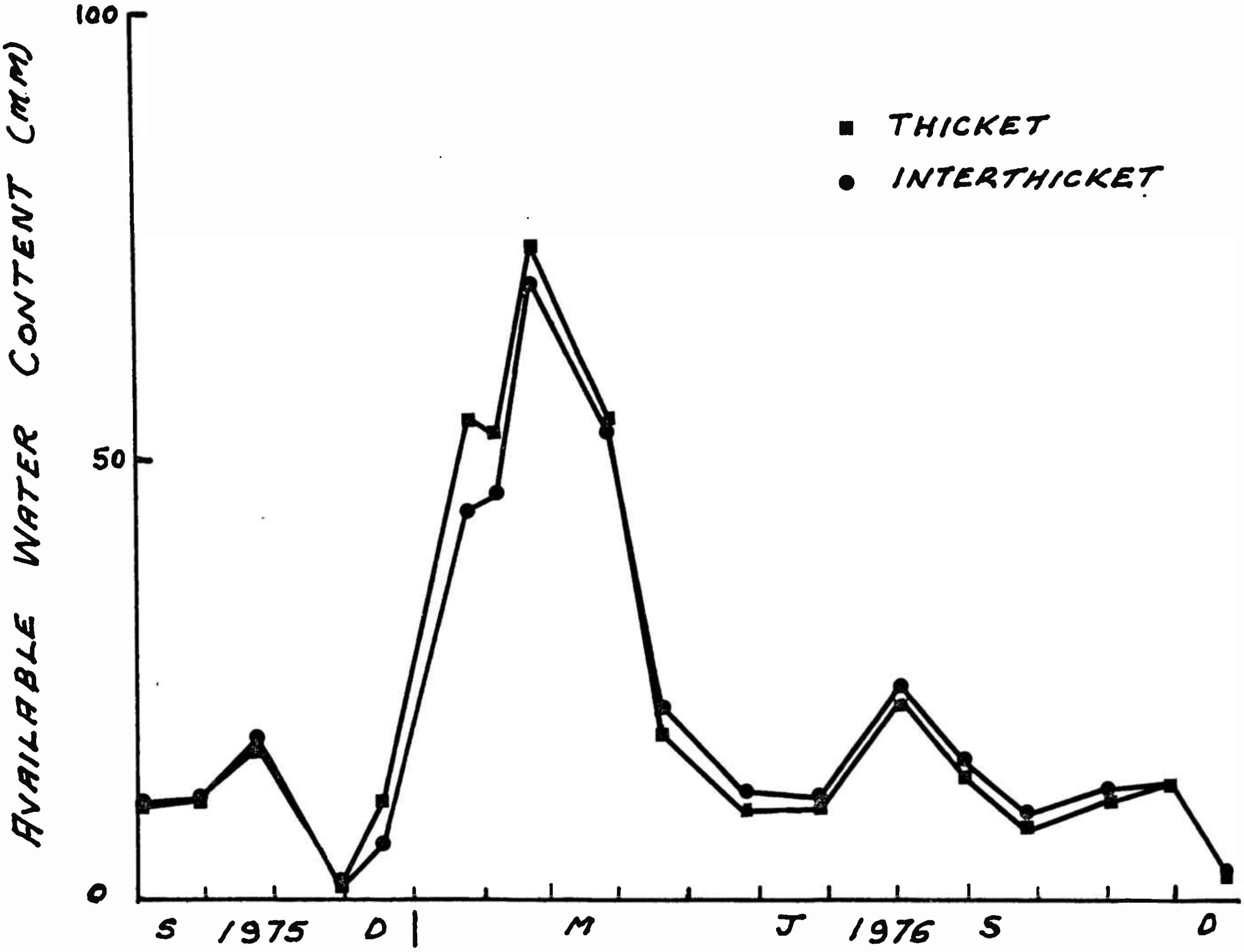

Figure 2. Available soil water content for thickets and inter-thicket areas. (Mean of all treatments).

The greater infiltration which occurs in the vicinity of the thicket appears to have caused more soil water to accumulate under the thickets during wet periods (Figure 2). During drier periods, however, the greater evapotranspiration associated with the greater biomass in the thickets caused the thicket soil profile to dry out to a greater extent.

The removal of the shrubs caused a 40% increase in available stored water during February, while prevention of eucalypt evapotranspiration by ringbarking caused a further 28% increase in available water at this time (Figure 3). Similar proportional effects were evident during other periods of the year.

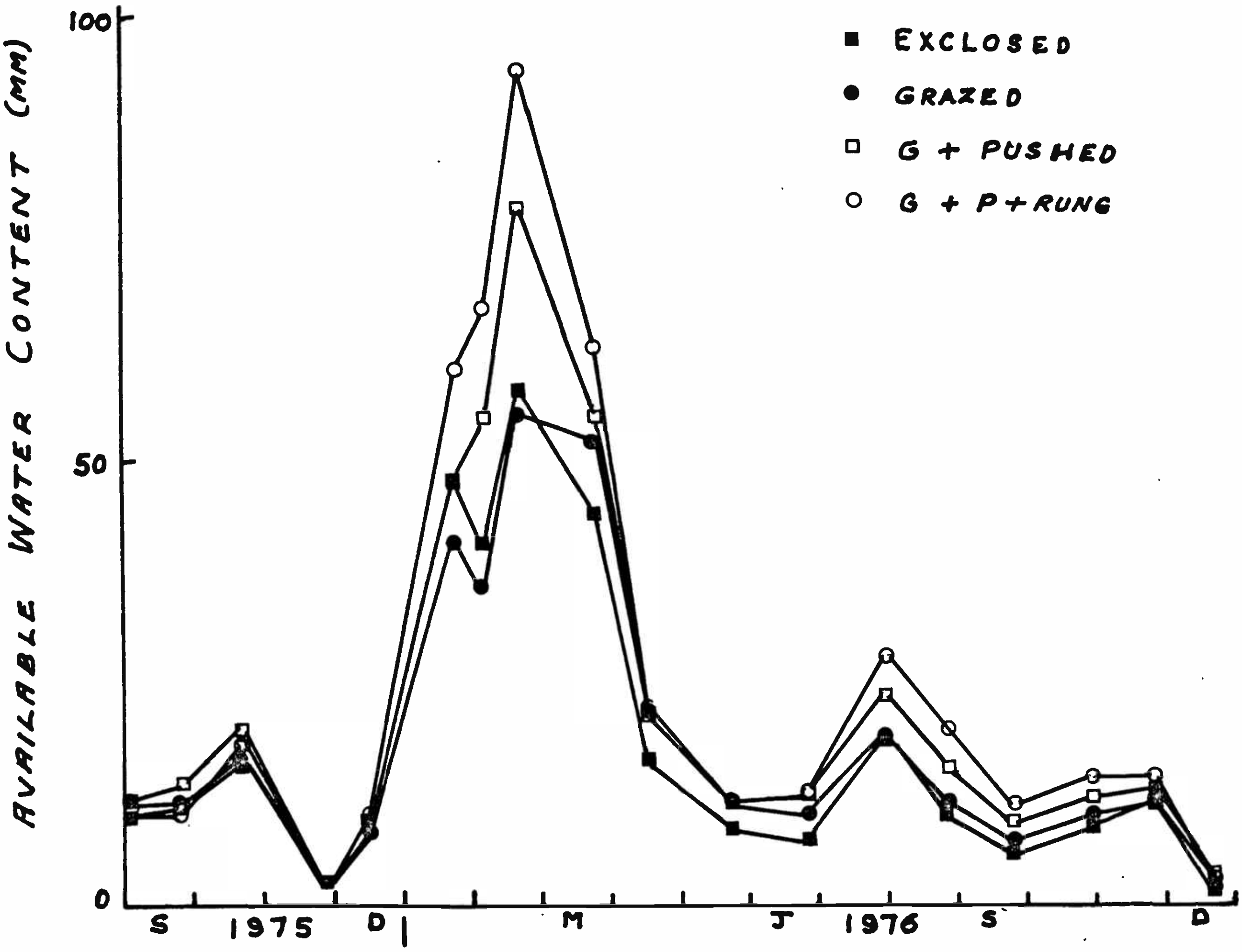

Figure 3. Influence of the four treatments on available water content.

The maximum quantity of available water that the Oakvale soil profile can hold is a very variable quantity, depending both on the amount of sand and gravel in the soil profile, and the depth to bedrock. NMM readings taken the day after the end of an extended wet period (February) indicate that on average the 0-7.5 cm zone holds 13 mm available water at field capacity and the 7.5-22.5 cm horizon holds 21 mm (Figure 4). The 22.5-67.5 cm zone has held 39 mm (March; probably, but not definitely at field capacity). The zone of variable thickness extending from 67.5 cm to 7.5 cm into bedrock (which ranges from 0-57 cm in thickness) has held anything from 0 to 103 mm of available water. Between November 1975 and March 1976, this zone gained available water as follows:

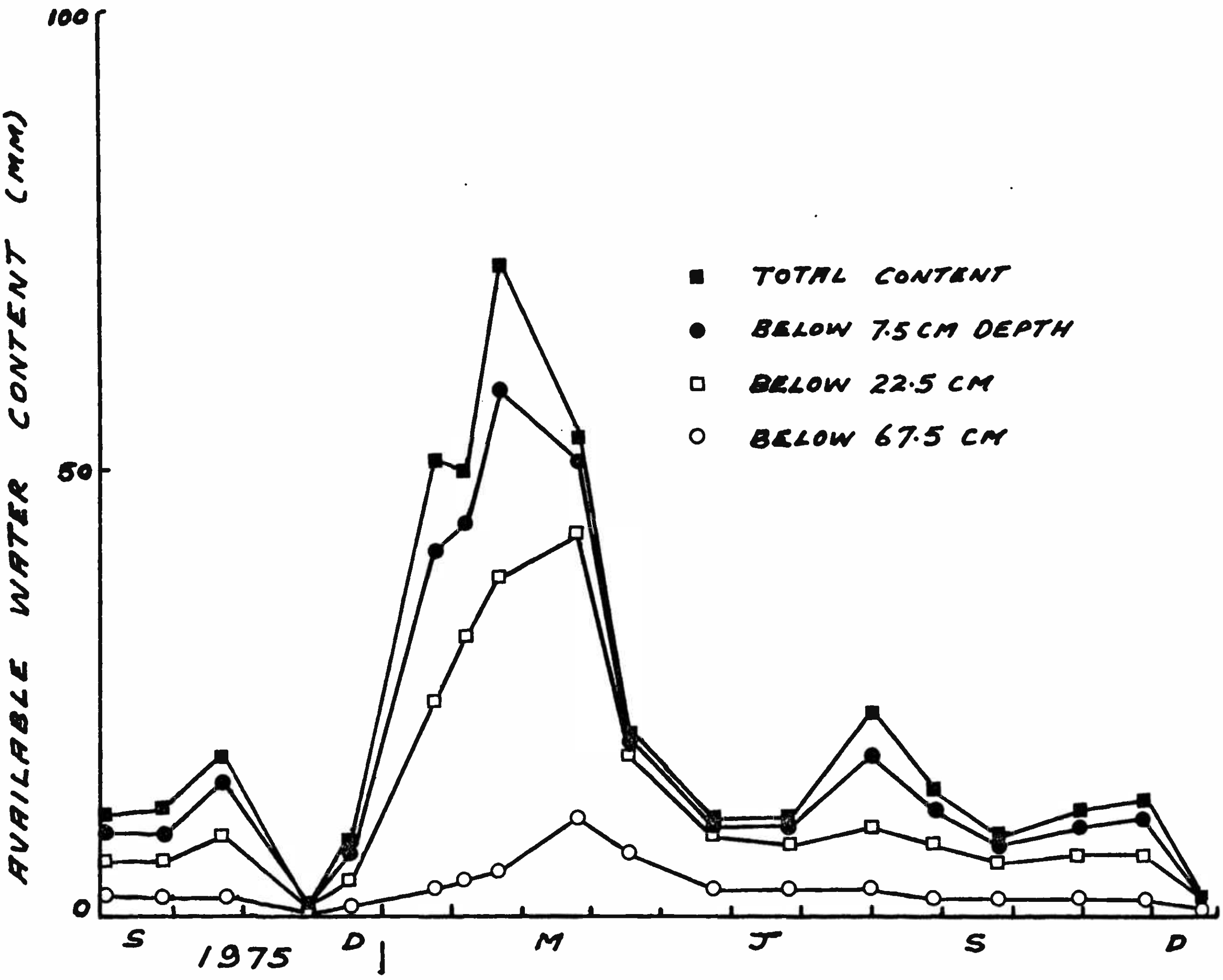

Figure 4. Distribution of available soil water within the soil profile. (Mean of all treatments).

gain of less than 5 mm	35% of holes
5 - 10 mm	23%
10 - 20 mm	27%
20 - 40 mm	12%
more than 40 mm	3%.

The average quantity of water held in this zone after the prolonged wet period was 11 mm, to give an average total profile available water content of probably slightly in excess of 84 mm.

Discussion

To illustrate the unusually wet nature of the early part of 1976 at Oakvale, the total calendar year rainfall of 639 mm considerably exceeded the 90 percentile value of 564 mm for Byrock, while the 50 percentile Byrock annual value is 339 mm.

The failure to measure runoff during the very wet Feb. 23 - Mar. 2 period is unfortunate. However, it will be possible to estimate fairly accurately how much runoff there was by using the water balance model currently under construction. The model is being constructed to simulate the soil water availability under the eight combinations of the four treatments by thicket and inter-thicket. Such a model can be used in conjunction with the relevant soil water records to estimate soil water immediately prior to and following a rainfall event, and thus enable the estimation of runoff.

As yet the goat grazing treatment has had no detectable effect on soil water availability when compared to the exclosed control. While this is not surprising, the current rapid increase in the amount of mulga (*Acacia aneura*) growing on the exclosed inter-thicket areas may at some time in the future cause lower soil water availabilities on these areas.

In assessing the runoff figures there is a need to weight them according to the area represented to determine the average for a treatment. As thickets occupy about 15% of the area (Harrington, personal communication) the weighted runoff means for cleared and undisturbed treatments respectively are 7% and 18%. The large apparent reduction in runoff due to clearing will probably not be sustained; the effects of disturbance on both the sorptivity of the soil surface and perhaps more importantly surface detention will probably decrease with time under the influence of both trampling and erosional redistribution of soil. Runoff measurements will continue for at least another 24 months to detect and follow any such trends. The ramifications of the effect of clearing on runoff for *in situ* herbage production, stock water collection, erosion and any water-spreading or contour-furrowing development are obvious.

The tendency of runoff from inter-thicket areas to be absorbed by thicket areas is not as important in this system as in the banded mulga system documented by Slatyer (1961). This is because a) the thickets occur virtually at random, and b) the centre of thickets are usually about 20 cm higher than the average of the surrounding inter-thicket area. Thus runoff from areas except those immediately upslope of the thicket tend to run around the thicket rather than into it.

Part of the water in excess of rainfall that infiltrates immediately upslope of the eucalypt may be due to stemflow. However, significant differences obtained between thicket infiltration with and without runoff plot installation indicates that the galvanised iron border of the runoff plots has prevented surface water from entering the thicket.

The rapid usage of soil water by the disturbed treatments (Figure 3) during the autumn of 1976 was most probably due to evapotranspiration by the very large quantity of herbage which grew on these areas following the wet period. While overall yield figures are currently still being computed, herbage yields of up to 3000 kg/ha dry matter from cleared thickets and somewhat less from the cleared inter-thicket areas were recorded.

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