THE EFFECTS OF UNIFORM THINNING AND PATCH CUTTING ON SOIL MOISTURE STORAGE IN THE BLACK SPUR CATCHMENTS, VICTORIA.

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Background: It is generally recognised that soil moisture storage plays an important role in the generation of surface water run-off (Mein et.al. 1988, Burch et al. 1987, Wheater and Weaver 1980). Following clearing on a forest watershed in West Virginia, Patrick and Reinhart (1971) attributed yield increases to an increase in soil moisture storage. On the Coranderrk catchment's Victoria, Duncan and Heeps (1980) found that soil moisture also increased following clearfelling. Similarly thinning of a *Eucalyptus marginata* forest in Western Australia resulted in an increase in soil moisture storage and Stoneman (1986) attributed the lack of a substantial streamflow increase to this factor. In separate studies of forest to pasture conversion in California and Western Australia, both Hibbert (1969) and Sharman et al. (1987) respectively observed an increase in soil moisture storage. Hibbert (1969) suggested that the greater availability of moisture in the upper soil layers following clearing, where it could be exploited by the shallow rooted pasture grasses, might result in a continued high evapotranspiration rather than the decrease which might be expected to result. Sharma et.al. (1987) found that soil moisture storage following clearing increased beneath a depth of one metre and attributed this to exploitation by the transpiring grasses. Saxton (1983) suggests that as soil moisture storage is an important component of the hydrological regime of a catchment, it merits detailed analysis. This paper examines the effects of uniform thinning and patch cutting on soil moisture storage in the Black Spur catchments, Victoria.

The Study Area: The Black Spur catchments, Victoria, form part of the North Maroondah Experimental Area (NMEA) 37°36'S and 145°36'E) (Figs 1 and 2). In the summer of 1976/77 the Melbourne and Metropolitan Board of Works (MMBW) carried out a series of treatments in order to establish the effects of forestry operations on the catchments. Thirty percent thinning, 50% thinning and 50% patch cutting were carried out in the Black Spur 2, 3 and 1 catchments respectively, with Black Spur 4 remaining untreated as a control (Fig 3).

A detailed physical description of the catchments is available in Langford and O'Shaughnessy (1979). Briefly, the geology of the catchments is described as quartz-biotite-dacite (Edwards 1932). The soils are described by Langford and O'Shaughnessy (1979) as consisting of typical kraznozems. They have a high infiltration and storage capacity and are

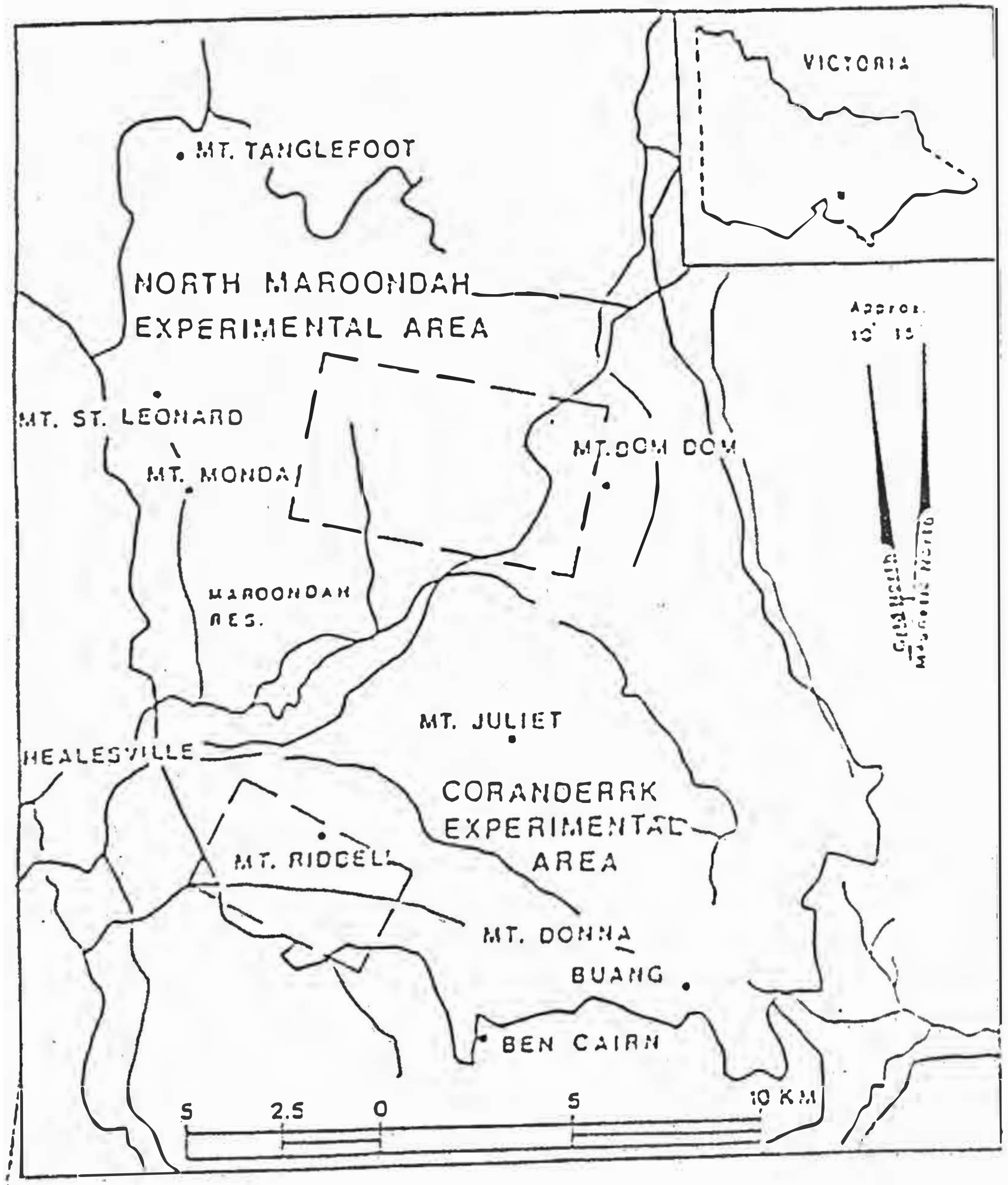


Figure 1 Regional Plan (Langford and O'Shaughnessy 1979)

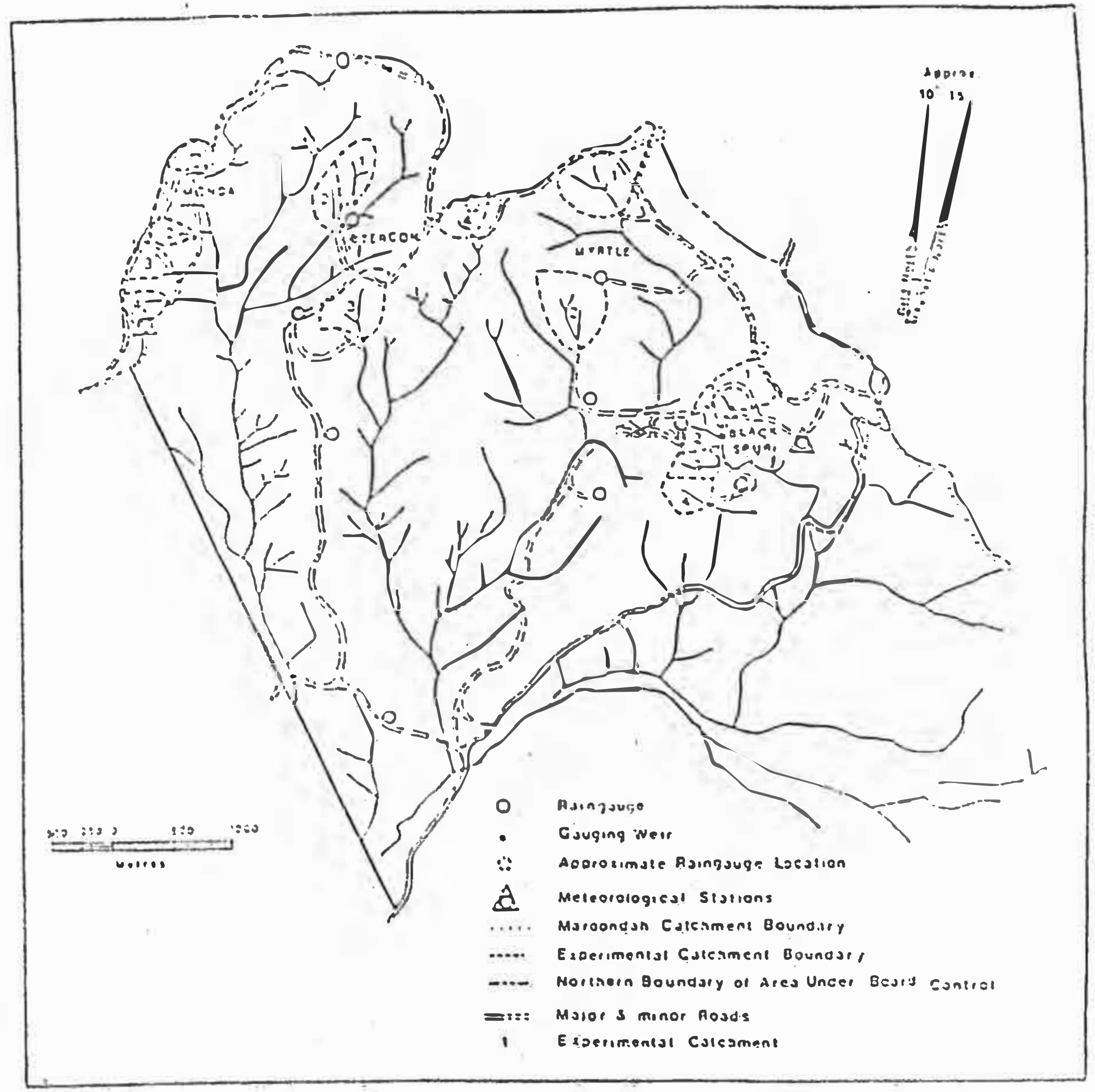


Figure 2 Location of Experimental Catchments Within the NMEA (Langford and O'Shaughnessy 1979)

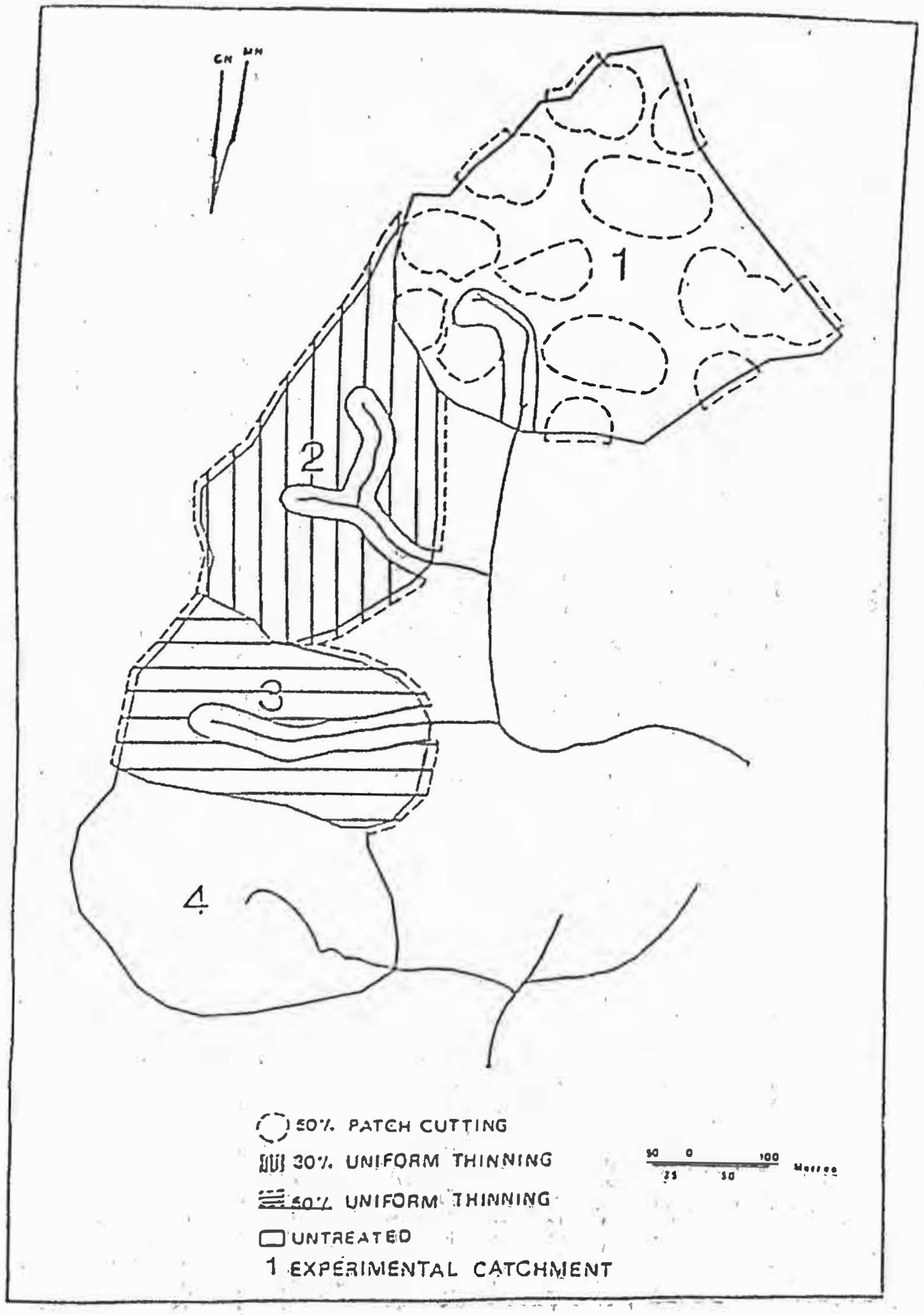


Figure 3 Logging Treatments - Black Spur Group (Langford and O'Shaughnessy 1979)

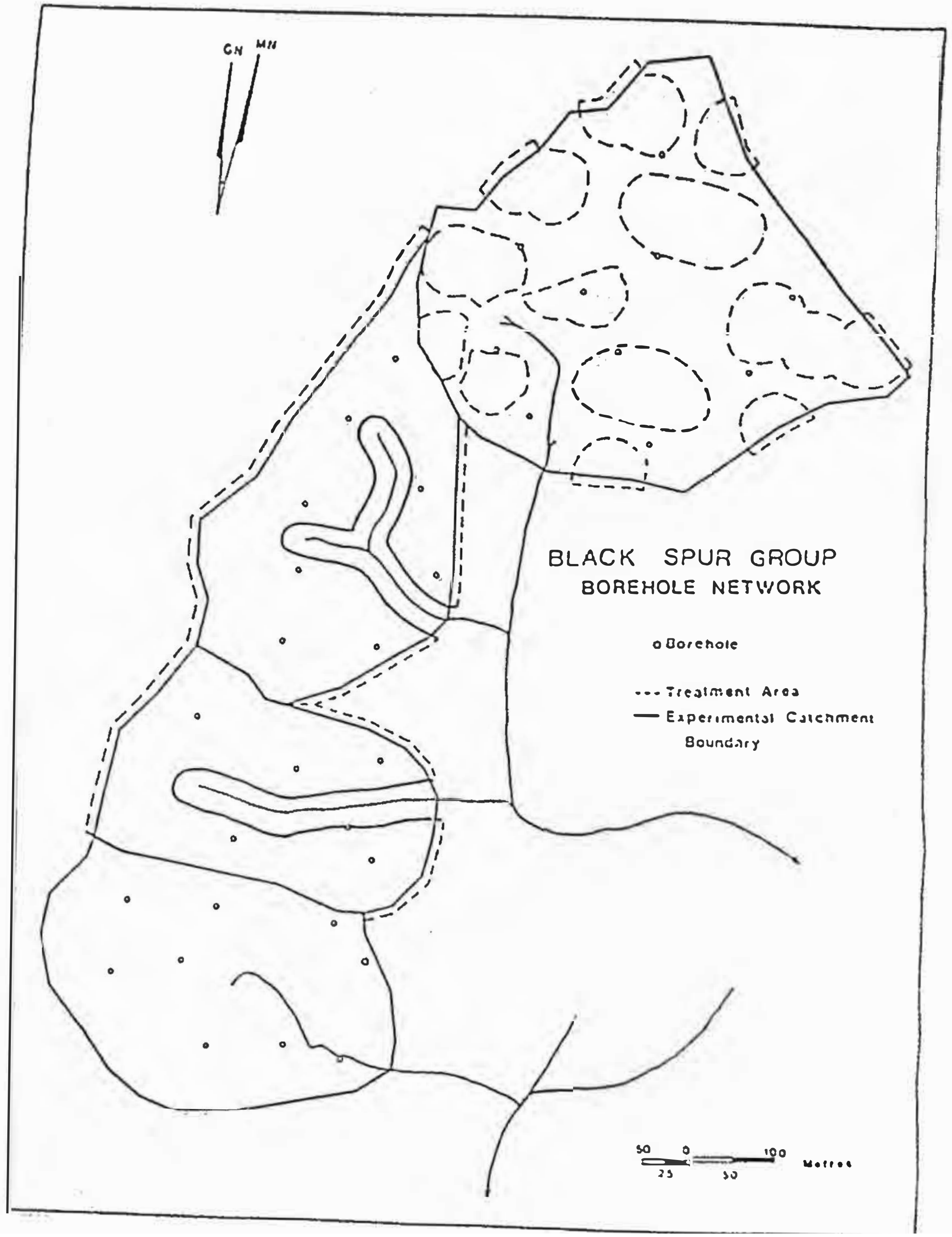


Figure 4 Borehole Locations Relative to Treatment (Langford and O'Shaughnessy 1979)

typically 10-15m in depth (Moran and O'Shaughnessy 1984). A high intensity bushfire swept the area in 1939 and the catchments are now vegetated by a regrowth mountain ash (Eucalyptus regnans) forest community. Scrub and gully communities occupy the stream valleys (Langford and O'Shaughnessy 1979). Under the Koppen system, the climate of the region is classified as Cfa and Cfb subtypes, being warm, temperate (C) and rainy (f), with the summer months being warm (b) to hot (a).

	BS1	BS2	BS3	BS4
Area (ha)	16.97	9.63	7.73	9.81
Perimeter (m)	1620.0	1393.0	1100.0	1183.0
Circularity Ratio	0.81	0.62	0.80	0.88
Max.Elevn. (m)	72.3	72.9	67.8	95.6
Drainage Density	1.38	3.63	3.76	2.67
Main Channel				
Length (m)	219.0	279.0	291.0	262.0
Relief (m)	30.0	34.0	33.0	45.0
Gradient (O)	7.7	6.9	6.4	7.8
Wetted Area (ha)	0.244	0.498	0.260	0.109

TABLE 1 PHYSICAL CHARACTERISTICS OF THE BLACK SPUR CATCHMENTS (LANGFORD AND O'SHAUGHNESSY 1979)

A winter dominated rainfall, with high summer evaporation losses characterise these catchments which fall within group 14 of the river regime described by Haines et.al. (1988). This group is described as having a streamflow with a broad winter and early to mid-spring peak, with a distinct yet low summer flow. The physical characteristics of the catchments are summarised in Table 1.

Instrumentation Network and Data Collection: Langford and O'Shaughnessy (1979) describe the installation of the Black Spur borehole network, shown in Fig 4. Selection of sites was made after a detailed survey of the catchments' physical characteristics. The number of boreholes was restricted by economic considerations but every attempt was made to ensure that the measurements obtained from the borehole network would closely approximate catchment soil moisture conditions.

In the Black Spur catchments soil moisture has been measured using two Troxler neutron probe moisture meters. The neutron moisture meter technique is outlined in detail in Greacen (1981). It relies on the ability of hydrogen to slow high energy neutron levels. The number of slow energy neutrons counted is related to the amount of water present in the soil (O'Connell 1976). A calibration equation is required to convert the neutron count to a given soil moisture content (Williamson and Turner 1978). Calibration of the Troxler Neutron Probe moisture meters used by the MMBW is described in O'Connell (1976) and Fiske (1983).

Soil moisture shield counts in the Black Spur catchments are converted to a volumetric moisture content (millimeters per metre) by means of the regression equation (Langford and O'Shaughnessy 1979):

$$Y = 589.3X \quad 193.1 \qquad r = 0.994$$

Where Y = moisture content (mm/m)

X = shield count ratios (counts in soil/counts in shield).

These values are then averaged over the catchment and accumulated to 5.2 metres.

Soil moisture has been monitored on these catchments to a maximum depth of 5.2 metres at thirty-three boreholes throughout the study area (Fig 4). Measurements have been made on a fortnightly to monthly basis over a ten-year period from 1973 to 1983.

Anomalous Values: During the analysis of the soil moisture data, it became apparent that a few readings (<2%) were anomalous (Fig 5). These readings were identified where the suspect value was inconsistent with the remainder of the soil moisture values for no apparent reason (i.e. they could not be explained by a storm or dry period). Checking of the original data files failed to explain the reason for these anomalous values. It appears, therefore, that they arose through recording error or equipment failure. In order to retain as many soil moisture measurements as possible, it was decided to adjust these figures rather than to discard them. In the pre-treatment period, this was done by using the regression equations derived for the catchments from measurements taken over the same period on the control catchment Black Spur 4. The pre-treatment regression equations are:

BS1	Y	=	0.86X + 490.43	r^2	=	0.92
				p	<	0.001
and						
BS3	Y	=	0.85X + 182.67	r^2	=	0.55
				p	<	0.001

Where

Y = soil moisture in the treatment catchment

X = soil moisture in Black Spur 4.

The r^2 value for Black Spur 3 is not particularly high and therefore the model is less strong than for Black Spur 1. It is apparent that this is due to the anomalous values already mentioned which are having a biasing influence on the equations. The removal of these values results in the following regression model:

Y	=	1.06X	267.14	r^2	=	0.90
				p	<	0.001

Where

Y = soil moisture in Black Spur 3

X soil moisture in Black Spur 4.

Where no reading had been taken in Black Spur 4 on a coincident date the anomalous value was abandoned and the figures averaged over the longer period. This latter procedure was also followed in the post-treatment period.

During the analysis of data, it became apparent that the effects of treatment in Black Spur 2 (30% thinning) were less significant than those of Black Spur 1 or 3. In a comparison of the results of the respective forestry practices these could add little to the study. For this reason they were not included; although a complete analysis has been made of these results.

Results - Soil Moisture Profiles: Catchment soil moisture profiles for the average summer minimum in the pre-treatment period were plotted against those of the post-treatment period. The drought year (1982) was excluded from these calculations in an effort to avoid bias introduced by extreme climatic conditions. In Black Spur 1 (50% patch cutting) the average soil moisture increase was 54.35 millimetres. Increases were greatest beneath 2.5 metres (Fig 6). These increases were uniform throughout the lower soil profile and continued to the maximum depth of measurement (5.2 metres). This indicates that the above figure derived for change in soil moisture is

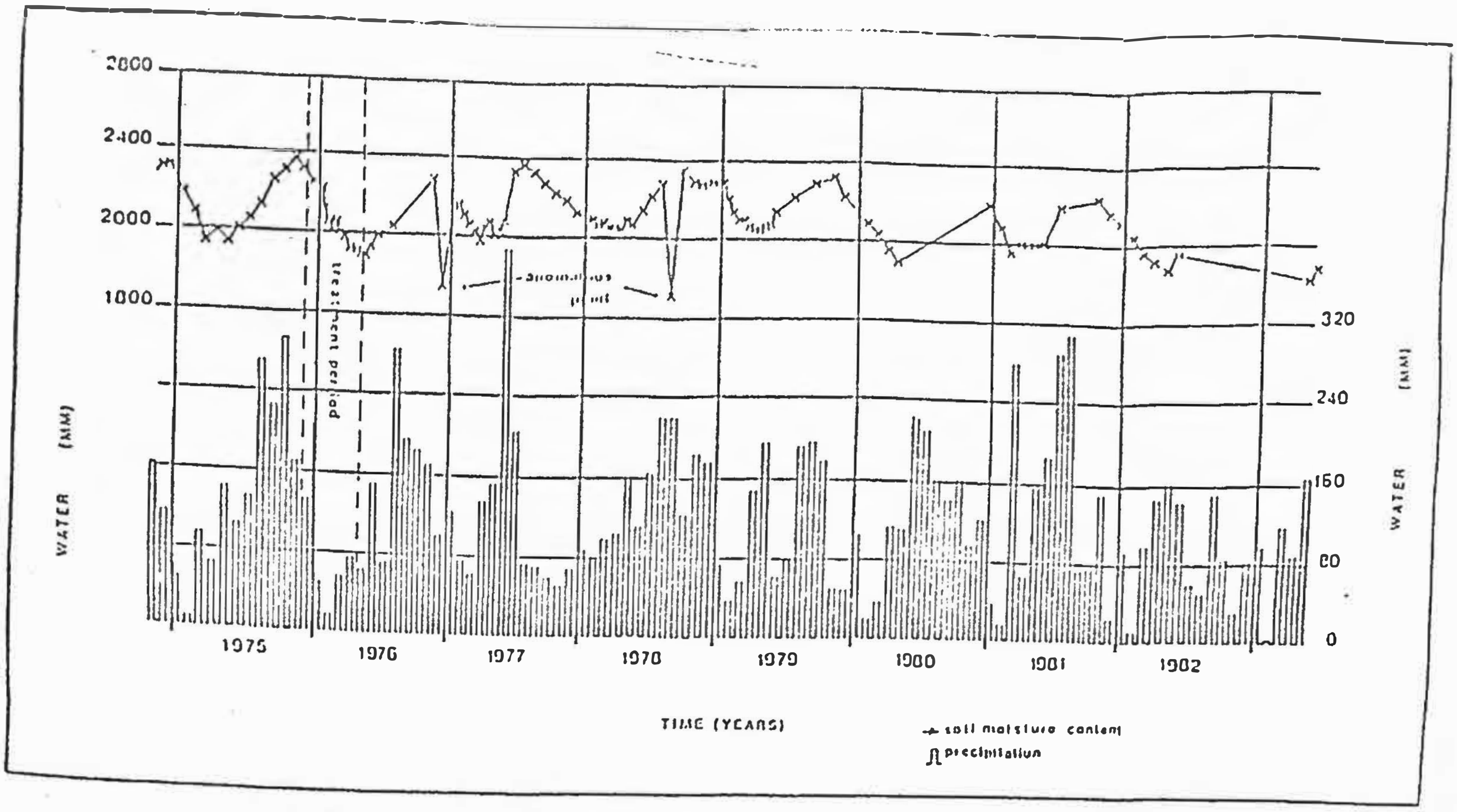


Figure 5 Soil Moisture and Precipitation Over Time - Black Spur 3

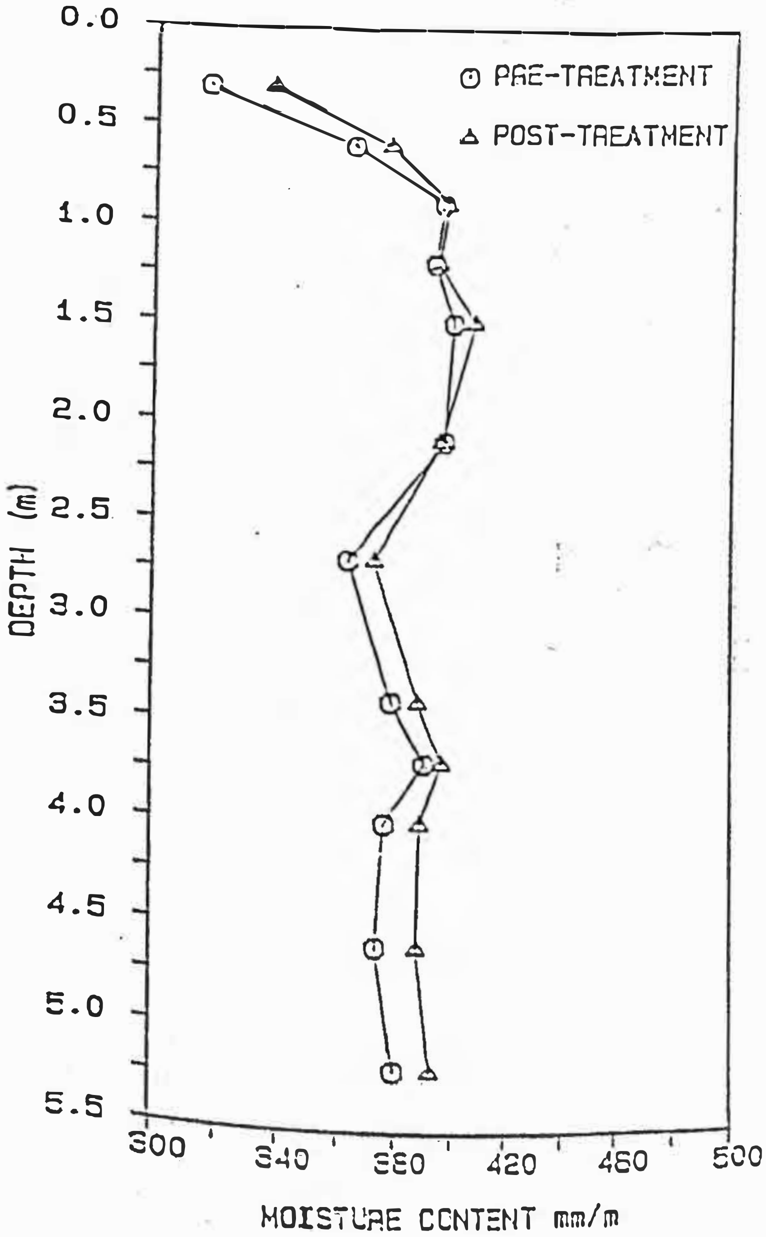


Figure 6 Average Summer Minimum Pre- and Post-Treatment Soil Moisture Profiles - Black Spur 1

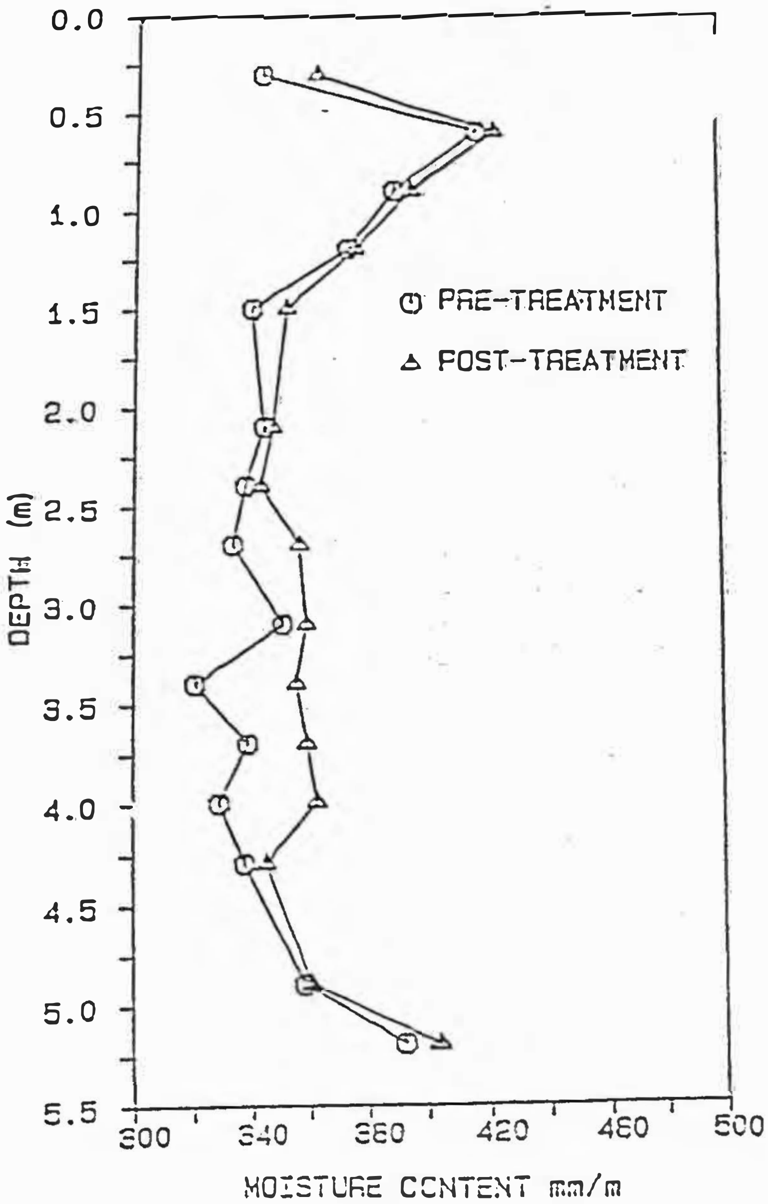


Figure 7 Average Summer Minimum Pre- and Post-Treatment Soil Moisture Profiles - Black Spur 3

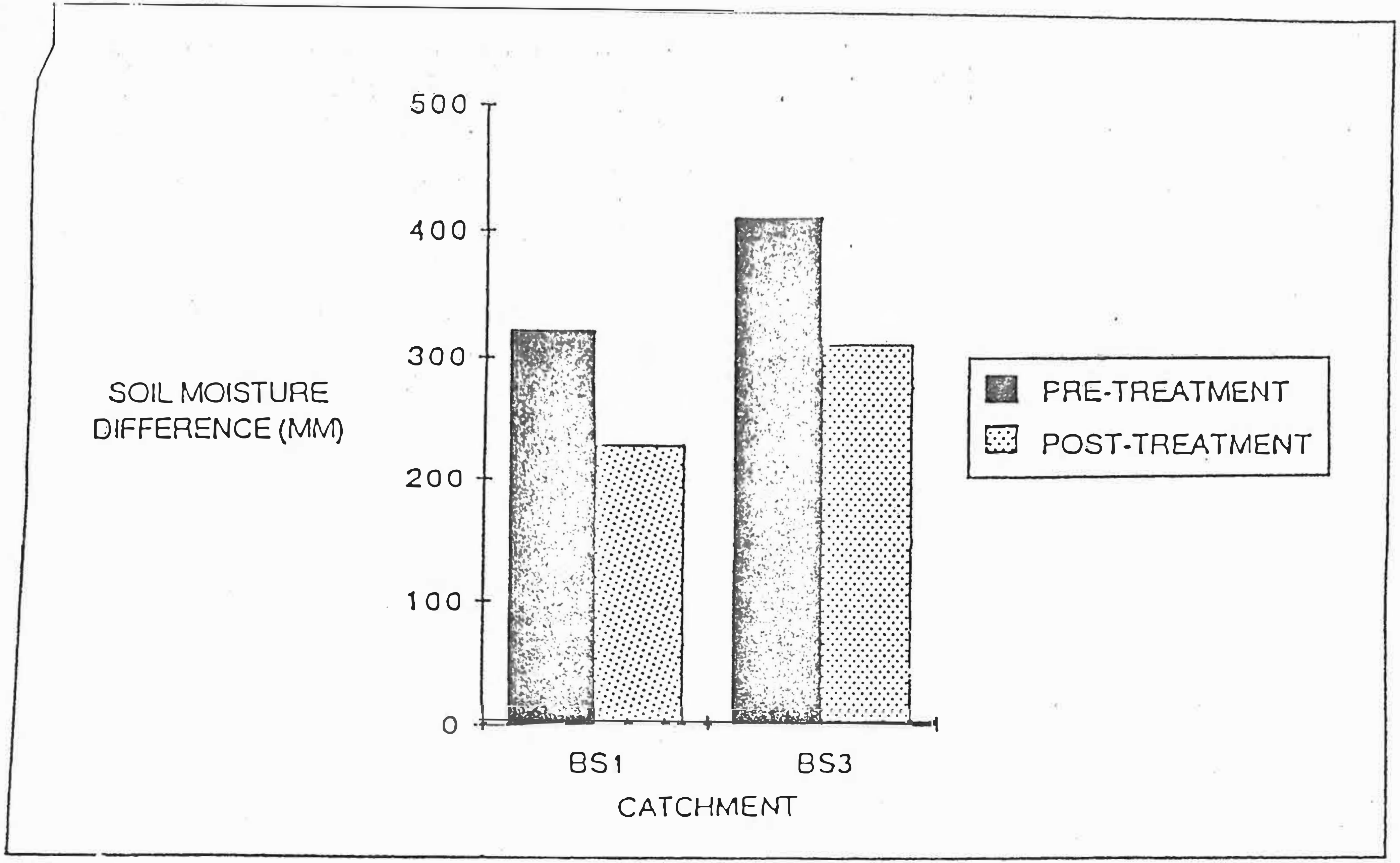


Figure 8 Mean Soil Moisture Difference Between Wet and Dry Conditions, Pre- and Post-Treatment - Black Spur 1 & 3

probably under-estimated in this catchment. In Black Spur 3 (50% uniform thinning) soil moisture increased by an average of 70.68 millimetres (Fig 7). In this catchment increases were greatest between 1.5 and 4.5 metres. At a depth of 5.2 metres in Black Spur 3 there is little fluctuation of soil moisture as a result of forestry practices, indicating that the soil moisture change figure obtained for this catchment is possibly a more realistic estimate than that of Black Spur 1.

Soil Moisture Variations Over Time: The soil moisture stores show a distinctly seasonal fluctuation (Fig 5). The greatest soil moisture values are attained during the winter/spring months, with values as high as 2600 millimetres, and the lowest during the summer/autumn months when values can be as low as 19 millimetres. Fig 8 shows the mean soil moisture difference between wet and dry conditions in the pre- and post-treatment periods for each of the catchments. Again, the drought year was excluded from these calculations. Black Spur 3 (50% uniform thinning) shows the greatest differentiation between wet and dry soil moisture conditions. In both catchments the difference decreased in the post-treatment period. The maximum difference over the 5.2 metre profile, between field capacity and permanent wilting point, is 320 millimetres for Black Spur 1 and 410 millimetres for Black Spur 3.

Persistence of Soil Moisture Change: In order to determine the effects of forestry practices on soil moisture storage, observed soil moisture was plotted against the predicted values obtained using the regression equations described (Figs 9 and 10). Soil moisture has increased in both catchments since treatment with the greatest increases occurring during the summer/autumn months.

To determine the relative importance of the increases the change in soil moisture (as defined by the difference between predicted and observed values) was plotted as a percentage of predicted soil moisture. A five point moving average was added to smooth the variability and to give some idea of the data trend (Figs 11 and 12).

Soil moisture in Black Spur 1 was higher during the summer/spring months for the first two years after treatment but rapidly returned to pre-treatment values (Fig 10). In winter, soil moisture values showed little change. In Black Spur 3 (50% uniform thinning (Fig 11) soil moisture increases were greater and much more persistent than those of Black spur 1. Like Black spur 1, the increases are higher in the summer/autumn months, although, in Black Spur 3, there was also some increase apparent in the winter months. This increase was not reflected in the soil moisture profiles and may be due to an under-estimation by the regression model

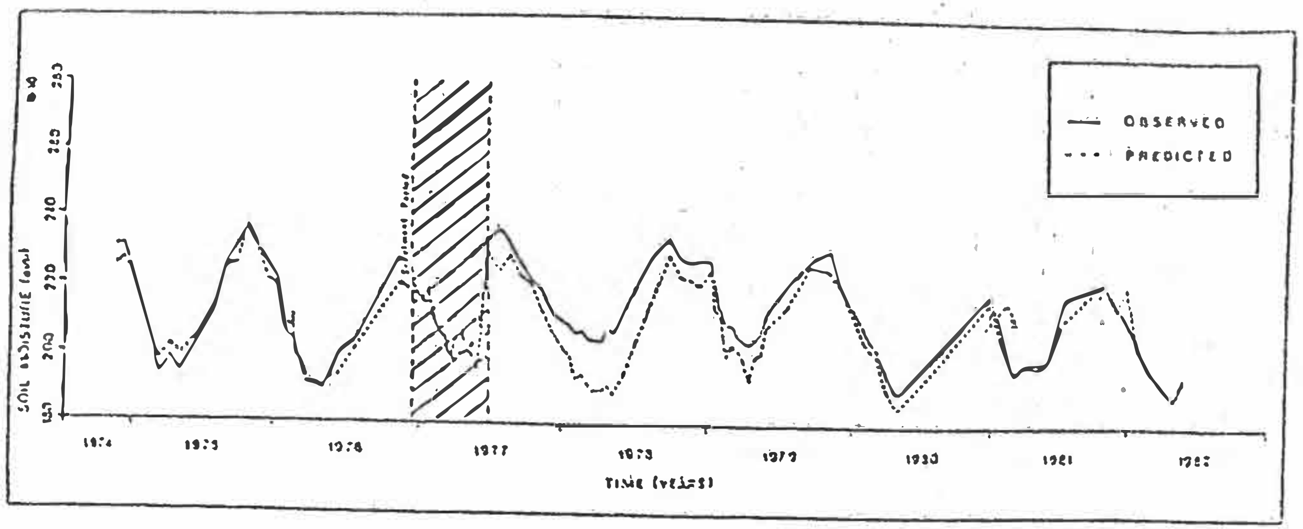
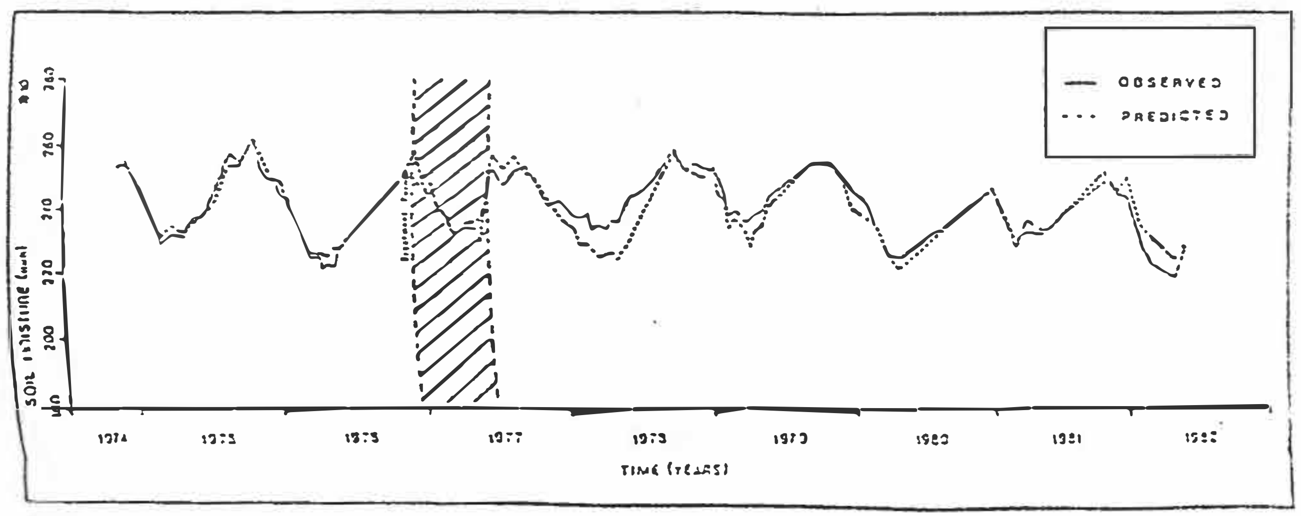


Figure 9 Observed versus Predicted Soil Moisture
- Black Spur 1

Figure 10 Observed versus Predicted Soil Moisture
- Black Spur 3



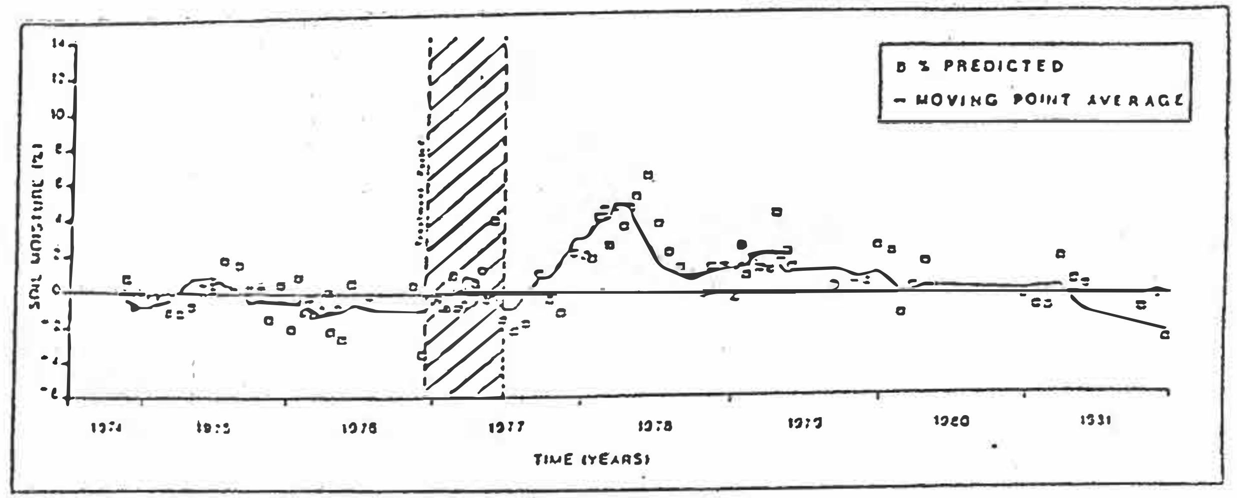
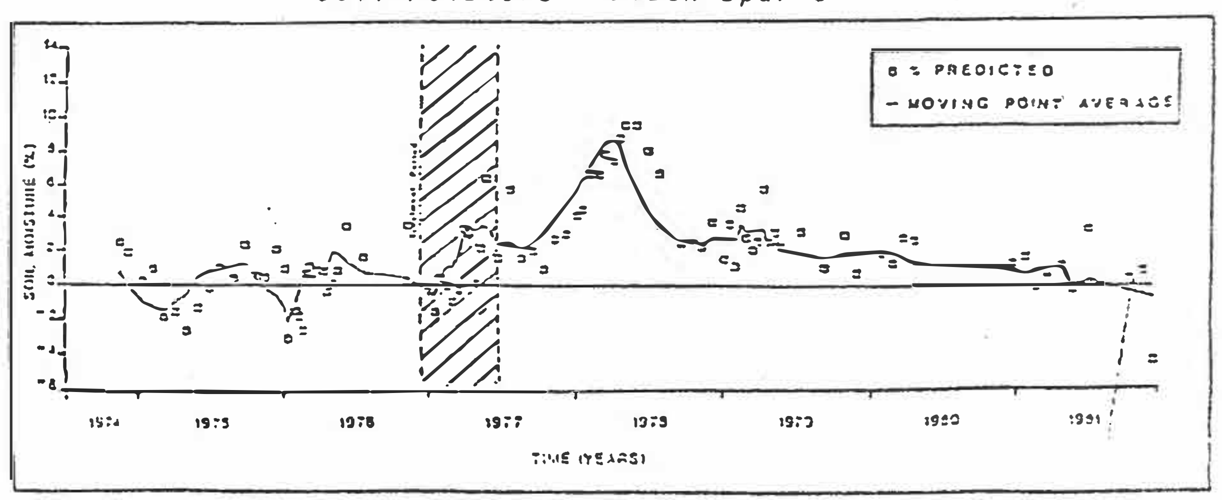


Figure 11 Soil Moisture Change as a Percentage of Predicted Soil Moisture - Black Spur 1

Figure 12 Soil Moisture Change as a Percentage of Predicted Soil Moisture - Black Spur 3



rather than other factors.

Discussion and Conclusion: The differential increase of soil moisture over depth and time suggests that the role of regrowth and remaining vegetation is important in determining the effects of forest treatments on soil moisture storage. A comparison of the results of both catchments suggests that the understorey vegetation exploits the top 1.5 metres of the soil profile for water. This is supported by the findings of Moran and Ronan (1978), in a study of vegetation rooting depths in the Black Spur catchments. The authors noted that the bulk of the root mass is to be found within the first 1.5 metres of the soil profile. It appears that in Black Spur 1, the regenerating overstorey vegetation is able to exploit soil moisture to a depth of 2.5 metres. However, in Black Spur 3 the removal of the deep rooted overstorey vegetation resulted in a greater increase in soil moisture beneath 1.5 metres.

Soil moisture increases are greatest in the summer/autumn months in both the pre- and post-treatment periods, probably due to the soil being at field capacity in the winter/spring months. The increased summer soil moisture store results in a decrease in the summer/winter soil moisture difference. The greater volume and persistence of soil moisture change in Black Spur 3 supports the findings of Langford (1976), that regrowth vegetation, such as that of the regenerated patch cut areas on Black Spur 1, utilises more water than an older forest.

The removal of deep-rooted overstorey vegetation by uniform thinning results in the greatest and most persistent soil moisture storage increases. In patch cutting soil moisture increases are smaller and less persistent due to the rapid regrowth of both understorey and overstorey vegetation species. These utilise more water and can exploit the soil moisture storage to increasingly greater depths.

This study has demonstrated that vegetation rooting depths have a major influence on soil moisture storage following uniform thinning and patch cutting.

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