PARWAN HYDROLOGICAL EXPERIMENTAL AREA

By

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By

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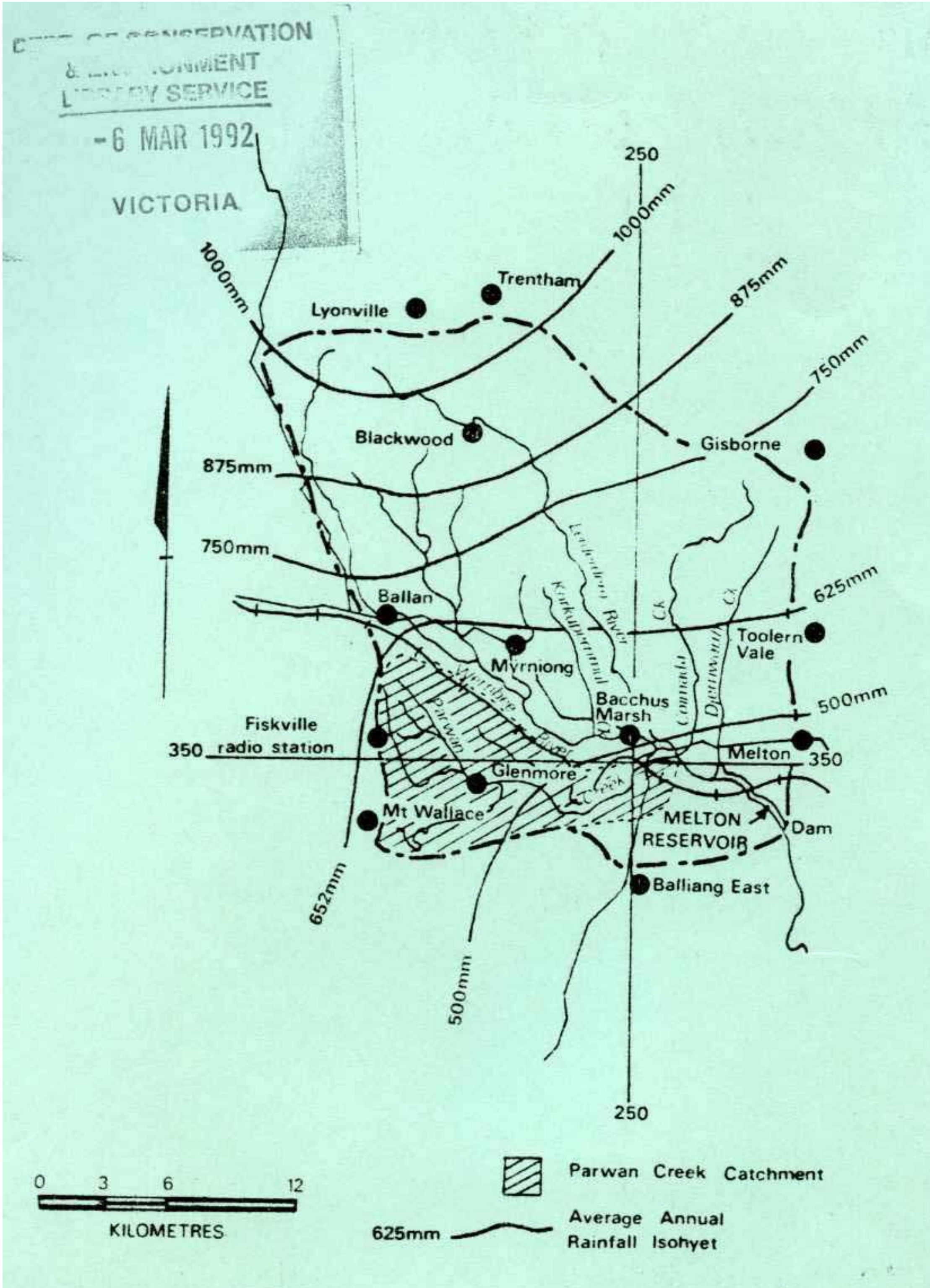
-6 MAR 1992
VICTORIA
250
1000mm
Trentham
875mm
Lyonville
750mm
Blackwood
Gisborne
875mm
750mm
625mm
Ballan
Toolern Vale
Myrniong
500mm
Bacchus Marsh
Fiskville radio station
350
Melton
Glenmore
Mt Wallace
MELTON RESERVOIR
Dam
Balliang East
652mm
500mm
0 3 6 12
KILOMETRES
Parwan Creek Catchment
625mm
Average Annual Rainfall Isohyet

Location

PARWAN EXPERIMENTAL AREA

1. Introduction

Since the publication of the report on Parwan Hydrological Experimental Area in September 1980, more results have been processed. A vegetation survey of the ground cover was made in 1983. This has contributed some understanding of land use changes, in particular the vegetation cover in relation to water movement in the soil erosion.

The early settlers in Victoria did not understand that environmental factors operating in this country. They used farm methods imported from elsewhere, and caused a great deal of damage to the land. Some of the land that was cleared turned out to be too marginal for agriculture and even pastoral use with the methods they understood, and accelerated erosion occurred.

Undoubtedly changes in land use will continue to be made, and it is important for the future of the country that appropriate management practices are used. Hydrological research should be directed to this area, to finding out more about the effects of land use changes on water and soil. This is also one of the tasks for Land Protection Division to investigate the environmental balances and consequently provide a firm basis for land us planning.

The Parwan Experimental Area is situated in a typical example of environmental damage in Victoria. The experimental area is situated about 16 km southwest of Bacchus Marsh. Following the clearing of vegetation by the early settlers, the occurrence of erosion has been widespread and the topsoil is nearly all gone.

The solodic soils there are characterised by a fairly shallow surface layer which changes abruptly to a stiff clay sub-sol having a considerably lower infiltration rate. The high erosion hazard on these soils is associated with the state of equilibrium between the vegetation, soils, and water; this is very sensitive and therefore easily upset. The need for a better understanding of this environment led to the establishment of the Parwan Experimental Area.

The experiment involves the measures of surface runoff from six small catchments of 1.6 ha each, and one large catchment area of 85 ha. Of the six small catchments, three are facing north and the other three south. Improved pasture of subterranean clover and Wimmera ryegrass was established on two of the small catchments, No. 2 with northern aspect, and No. 5 with a southern aspect, while the others were left in their natural state to act as controls. Two of these are predominantly native woodland and the other two native pasture, with one of each facing north and the other south. The first cycle of improved pasture of Wimmera ryegrass and subterranean clover has been completed. The second cycle improved pasture was started in 1979, top dressed annually with 187.5 kg/ha of superphosphate.

The pasture species are *Phalaris tuberosa*, *Currie cocksfoot*, *Woogenellup sub-clover*, and *Crimson clover*. All of them are common to the local grazing farm establishment. Owing to drought in recent years, this pasture has not yet fully developed.

Most of the experimental area is undulated with ten per cent steep slope. It is situated on the northern side of a badly eroded hill known as the White Elephant and is within the catchment of the Melton Reservoir. The vegetation was originally savannah woodland, but as a result of clearing and grazing, the surface is now only lightly covered with vegetation which offers the soil little protection from rain. The average rainfall in this area is 530 mm per annum which is not particularly high. However the soils become water-logged with rains of high intensity and long duration, especially during late winter. This causes landslips and both sheet and tunnel erosion. Rabbits also caused severe scarring of the landscape with their burrows, until some control was achieved by poisoning and fumigation.

The most eroded section within the experimental area is the White Elephant Hill. This hill was cleared of its trees and shrubs, and then grazing rabbits removed the remaining vegetation. This enabled the rain to beat directly onto the soil surface until it washed the topsoil away from the roots of the grass, and formed gullies. The hill is now riddled with tunnel erosion and shifting masses of soil. Siltation of the flats in the area is widespread due to intense sheet erosion, and valuable land is covered by debris, sand and silt. Various diversion banks have been constructed by the Division in an attempt to divert the runoff from the White Elephant Hill and deposit the silt on the area immediately below. The maintenance of these works must be continued if they are to be successful. The Land Protection Division is trying to improve the area by encouraging vegetative growth, by planting tees and keeping the rabbit population under control.

2. Equipment for Experiment Area

Photo 1 shows the climate station. The area is 12 m x 12 m, surrounded with a wire fence to keep out livestock and fauna. It consists of a Stevenson Screen which contains maximum, minimum, dry and wet bulb thermometers, plus a Thermohygrograph. There is also a standard rain gauge, a rainfall recorder, two evaporimeters (Australian sunken tank and a U.S. Class A pan), and an anemograph which records wind speed and direction.

In all six catchments and in the main channel there are A35 water level recorders for measuring direct runoff. The charts in the recorders run for six months but are checked weekly. Time and date are recorded on the chart for later reference. Photo 2 shows the weir structure and A35 water level recorder.

Soil moisture measurements are made by a neutron moisture problem in each catchment. The measuring depths are at 0.3 m, 0.6 m, 0.9 m and 1.2 m readings are taken weekly.

Two sets of soil thermometers have been installed at each catchment since 1973. Each set contains two soil thermometers, one at 0.5 m depth and the other at 1 m. Two extra rain gauges were attached to the A35 water level recorders – one at Catchment No. 3 (northerly aspect) and one at Catchment No. 6 (southerly aspect). These rain gauges check the rainfall variation, and more importantly synchronize the time during the period of rainfall and runoff.

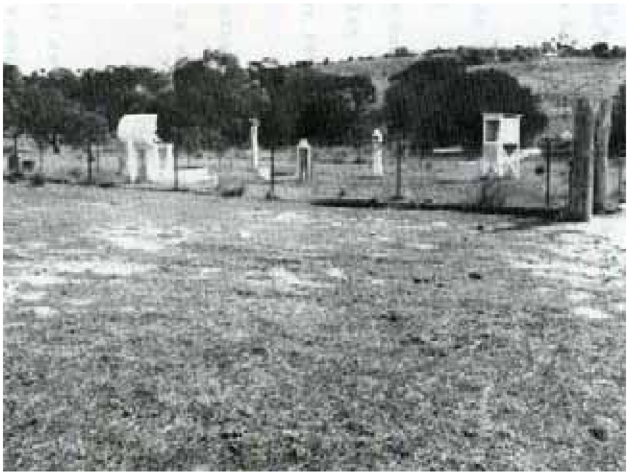

Photo 1 – The climate station

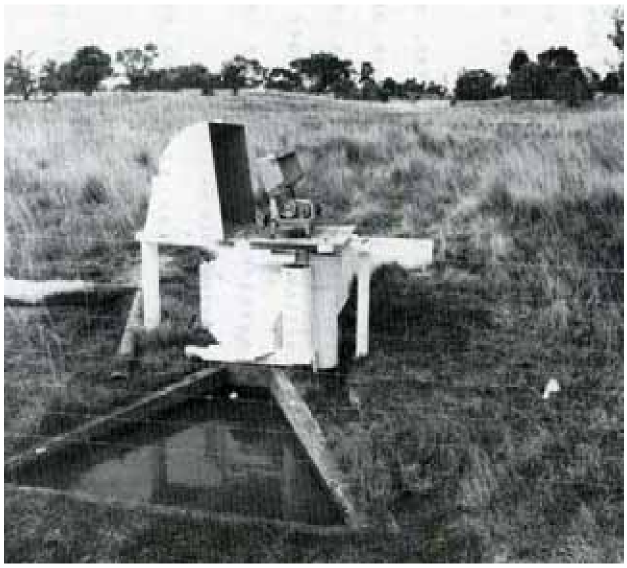

Photo2 – The weir structure and A35 water level recorder

3. Soil

The Parwan soil profiles on both aspects were examined in soil pits, and the soil classified in the great soils group of solodic soils. A description of the profiles is as follows:-

A1	0 – 50 mm	Grey brown slightly gravelly, fine sandy loam, fine granular structure.
A2	50 – 100 mm	Pale brown gravelly, fine sandy loam, fine angular blocky structure.
B1	100 – 600 mm	Dark red heavy clay, coarse subangular block structure merging into B2.
B2	up to 1050 mm	Reddish brown heavy clay, medium angular blocky structure merging into reddish brown and reddish yellow mottled fine sandy clay, massive angular blocky texture merging into C.
C	at 1050 mm	White pipe clay with reddish streaks.

Other observations made in vicinity from holes dug by auger showed similar profiles.

There are several main differences in the soils on the two aspects. Shallower A horizons occur more on the northerly aspects than on the southerly, and also there is a sharper boundary between the A and B horizons on the northerly aspect.

Although the A1 horizon has a comparatively light texture, surface compaction which followed the removal of vegetation and raindrop action has converted these soil surfaces to a hard impervious crust in many places. The A2 horizon has a very poor structure, and when wet it quickly loses stability. These characteristics are partly responsible for the widespread occurrence of tunnel erosion.

4. Vegetation

The experimental catchments support a natural pasture with isolated occurrences of trees and shrubs. The dominant tree species in the area are *Eucalyptus melliodora* (yellow box), *E. hemiphoia* (grey box) and *E. leucoxylon* (yellow gum).

There are scattered occurrences of smaller trees and shrubs which include *Acacia mollissima* (black wattle), *Acacia acinacea* (gold dust wattle), *Bursaria spinosa* (sweet bursaria) and *Hymenanthera dentate* (tree violet). The main perennial grasses in the natural pasture are *Poa calspitosa* (tussock grass), *Themeda australia* (kangaroo grass), *Stipa* spp. (spear grasses) and *Danthonia* spp. (Wallaby grasses).

Annual grasses include *Vulpa bromoides* (barren fescue), *Bromus mollis* (soft brome) and *Agrostis avenacea* (blown grass).

The pasture is better developed and there is a greater percentage of perennial grasses on the southerly aspect. Weeds are more common on the northerly aspect. For the improved pasture (Catchment No. 2 – northerly aspect and Catchment No. 5 – southerly aspect) subterranean clover (Trifolium subterraneum) and Wimmera ryegrass (Lolium rigidum) were established with the stocking rate set at 4.5 sheep per hectare. This experiment was completed in 1977. A paper entitled "Some Effects of Grazing on the Hydrological Properties on an Improved Pasture" has been published by the Institution of Engineers, Australia (Agricultural Engineering Conference, August 1978). In order to server the local grazing requirements, a new experiment was started in 1979. The pasture species are *Phalaris tuberosa*, *Currie cocksfoot*, *Woogenellup sub-clover* and *Crimson clover*. All of these are common to the local grazing farm practices. Although the improved pasture catchment is topdressed annually with 187.5 kg/ha of superphosphate, the pasture has not yet fully established owing to the drought in recent years.

Since 1975, only vermin and nomadic grazing occurred in Catchments 1 and 4.

Wattle trees were removed from the two catchments as many had become old and were dying. In 1975, a slow fire burnt through both catchments. This resulted in profuse wattle tree germination and the catchments re-established their wattle understorey. In 1978 a rabbit-proof fence was erected around catchments 1 and 4 and rabbit elimination was carried out. As a result, a good stand of native grass has developed in these catchments. Since 1975, some kangaroos have returned to the area, grazing in both catchments.

A vegetation survey was carried out in August 1983 after a prolonged period of drought which was followed by good autumn and winter rain. The cover at the time was considered to be average for that time of year. A similar survey had been made in March 1954. The results of average vegetation cover are listed in Table 1.

Catchment	1	2	3	4	5	6	7
Vegetation cover in 1954	38.9%	37.8%	40.9%	56.5%	60.6%	68.4%	50.5%
Vegetation cover in 1983	86.0%	42.5%	40.7%	85.0%	86.5%	87.5%	71.4%

Table 1 – Results of vegetation cover survey between 1954 and 1983

From Table 1 it is obvious that Catchment 1 in the northern aspect, with both native trees and grasses and without grazing, achieved the best results in vegetation cover, starting from 38.9% in 1954 and increasing to 86.0% in 1983 – an increase of 47.1%. Catchment 4 in the southern aspect had an increase in vegetation cover of 28.5% during the same period. The trend in the improved pasture is just the reverse. The vegetation cover in Catchment 2, with a northern aspect, the increase was 25.9%. For the control catchments there was virtually no increase in vegetation cover in Catchment 3 but with the southern aspect there was an increase of 19.1% in Catchment 6. Overall the average vegetation cover has increased by 20.9% during the past 19 years.

For easy comparison, two diagrams are included in here. Diagram 1 shows the northern aspect of vegetation cover in percentage and diagram 2 shows the southern aspect of vegetation cover.

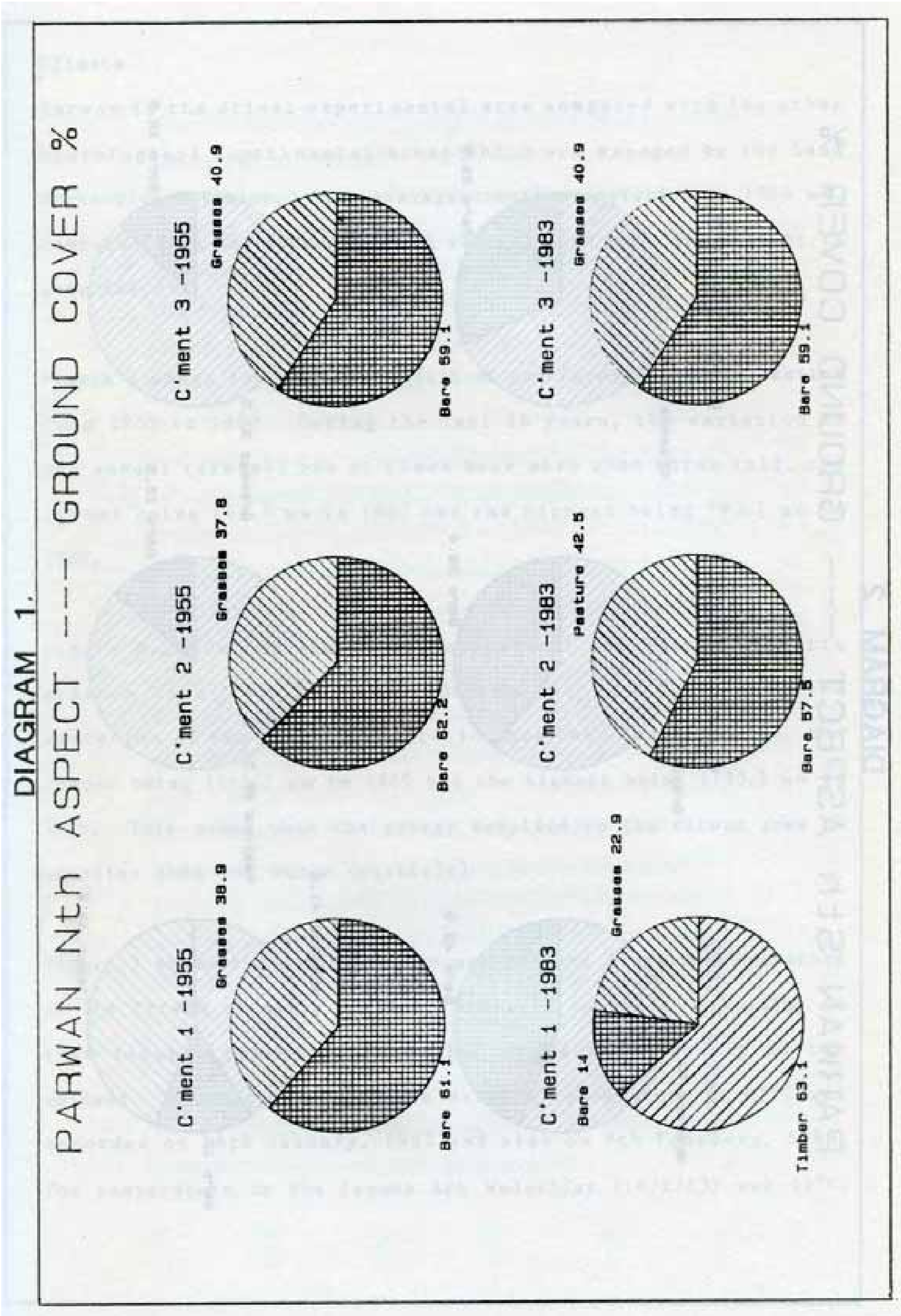

Diagram 1 – Parwan Nth Aspect – Ground Cover %

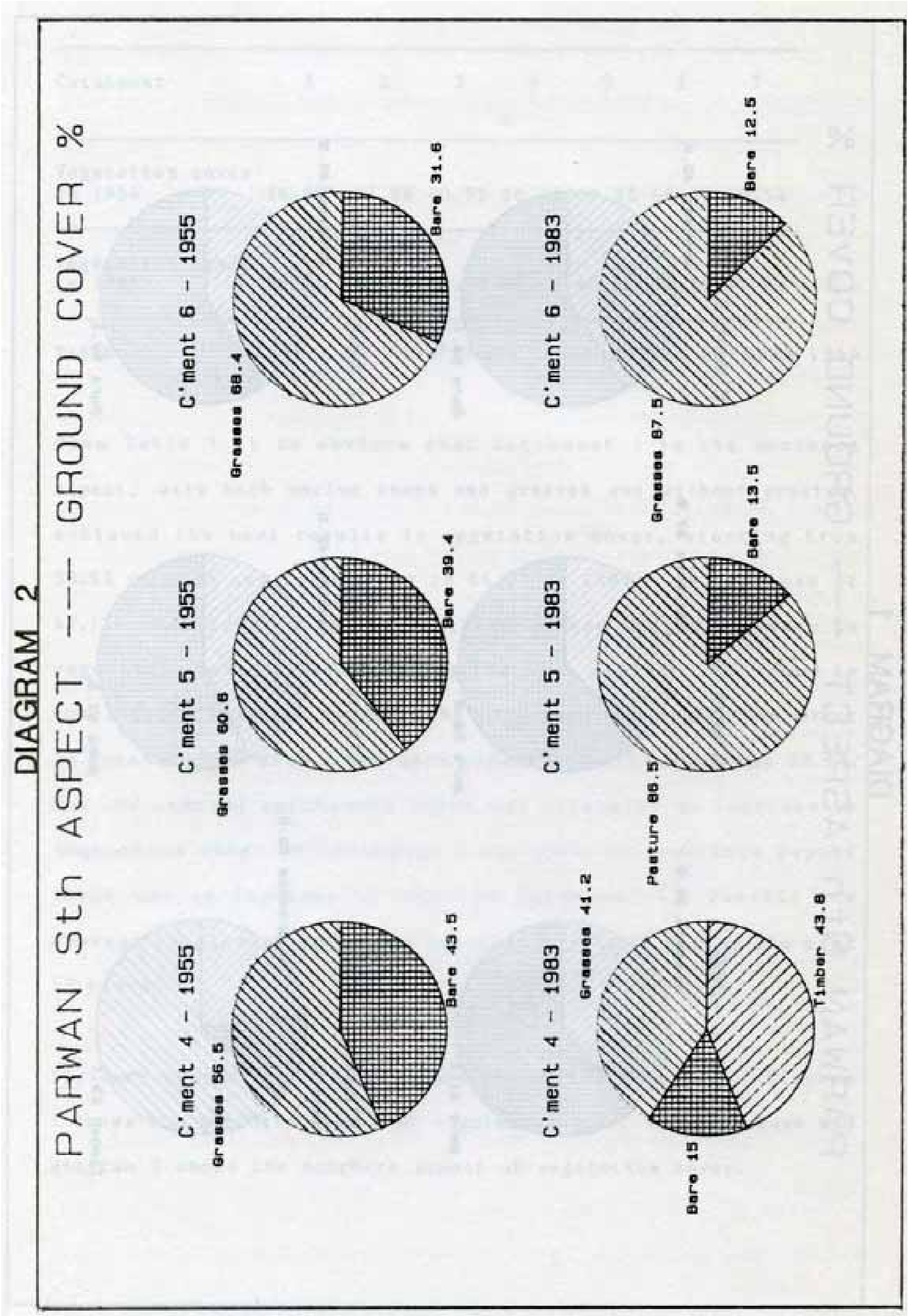

Diagram 2 – Parwan Sth Aspect – Ground Cover %

5. Climate

Parwan is the driest experimental area compared with the other hydrological experimental areas which are managed by the Land Protection Division. The average annual evaporation is 1386 mm, compared with the average annual rainfall 508 mm. The deficit is over 800 mm.

Figure 1 shows the annual rainfall at the Parwan climatic station from 1955 to 1983. During the last 28 years, the variation in the annual rainfall has at times been more than three fold, the lowest being 244.7 mm in 1967 and the highest being 793.1 mm in 1970.

Figure 2 shows the annual evaporation at the Parwan climatic station from 1956 to 1983. During the last 27 years, the variation in the annual evaporation has been less than 50%, the lowest being 1161.2 mm in 1960 and the highest being 1730.3 mm in 1976. This means that the energy supplied to the Parwan area is steadier than the water (rainfall).

Figure 3 shows the daily average maximum and minimum temperature at the Parwan climatic station from 1971 to 1983. According to this figure, February is the hottest month and July is the coldest. However, the absolute maximum temper of 43^{o}C was recorded on 24th January, 1982 and also on 8th February, 1983. The temperature on the famous Ash Wednesday (16/2/83) was 42^{o}C.

The absolute minimum temperature of -7^{o}C was recorded on 17th July, 1982. This demonstrates the variation in temperature in the Parwan area.

Figure 4 shows the daily average maximum and minimum relative humidity at the Parwan climatic station from 1971 to 1983. July is the most humid month of the year, while January is the driest.

Figure 5 shows the hours of sunshine per day, based on average monthly data from 1956 to 1959, at the Parwan climatic station. Since the energy supplied by the sun is relatively steady, it is not necessary to keep long-term records. January has the most hours of sunshine while July has the least.

Figure 6 shows the daily evaporation, based on average monthly data from 1955 to 1983, at the Parwan climatic station. The maximum rate of evaporation occurs in January and the lowest between June and July.

Figure 7 shows the long-term monthly rainfall. The highest rainfall occurs in October and the lowest in June.

Figure 8 shows the average daily wind speed, based on monthly data, from 1956 to 1983, at the Parwan climatic station. The wind speed is more or less evenly distributed – around 200 km per day. The only exception is February, during which it is 50 km per day higher.

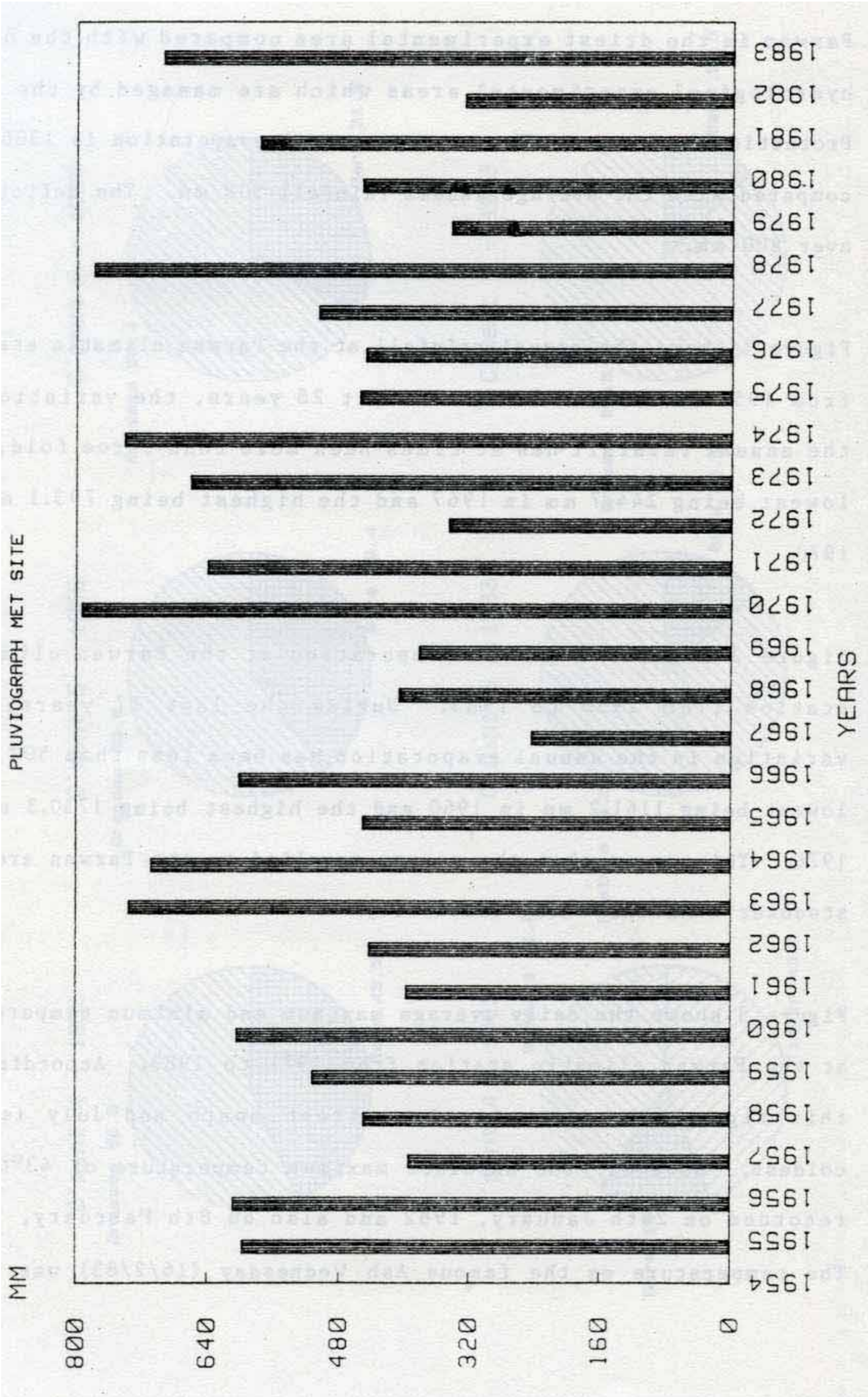

Fig 1 – Parwan Annual Data since 1955 – Rainfall

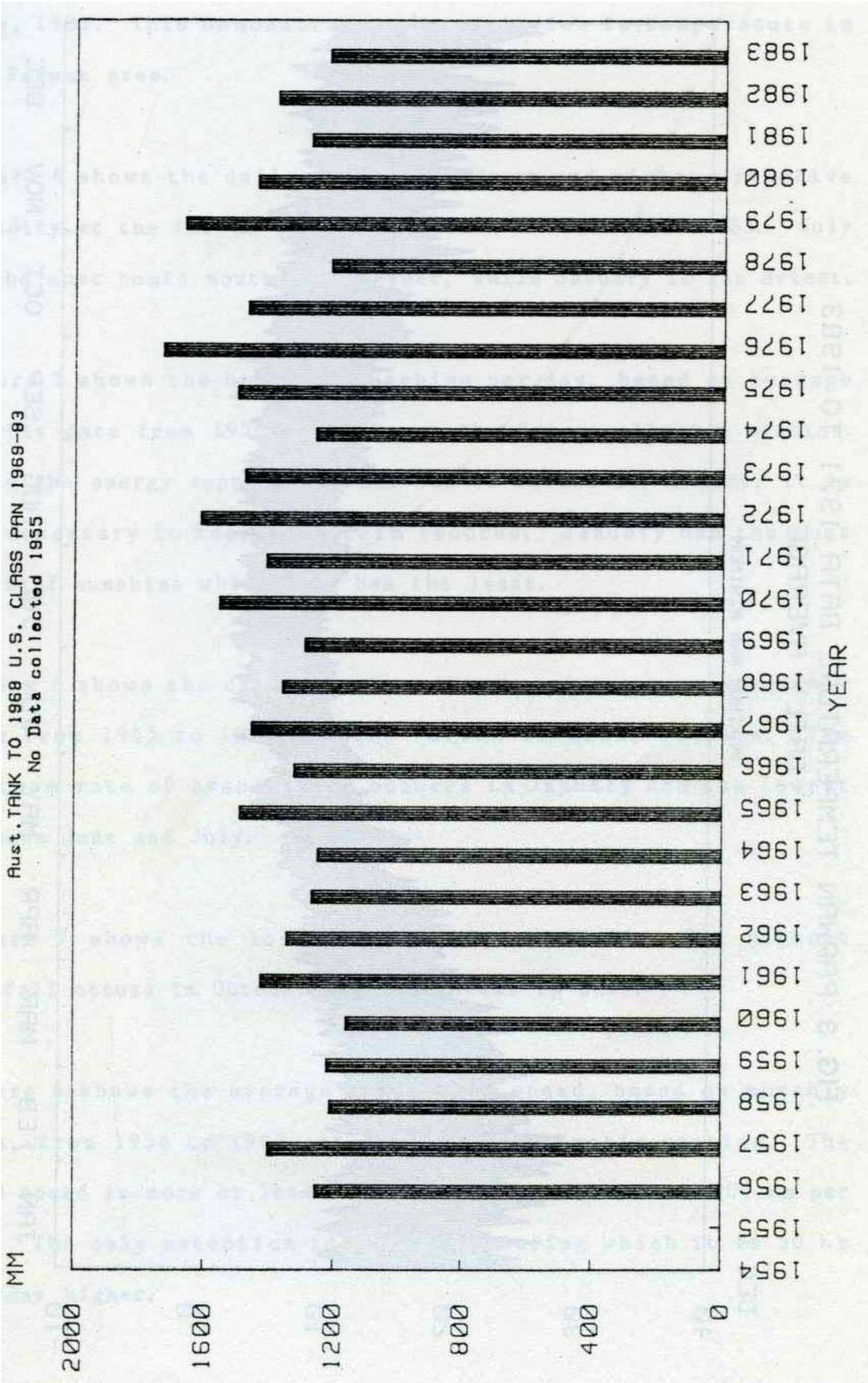

Fig 2 – Parwan Annual Data since 1956 – Evaporation

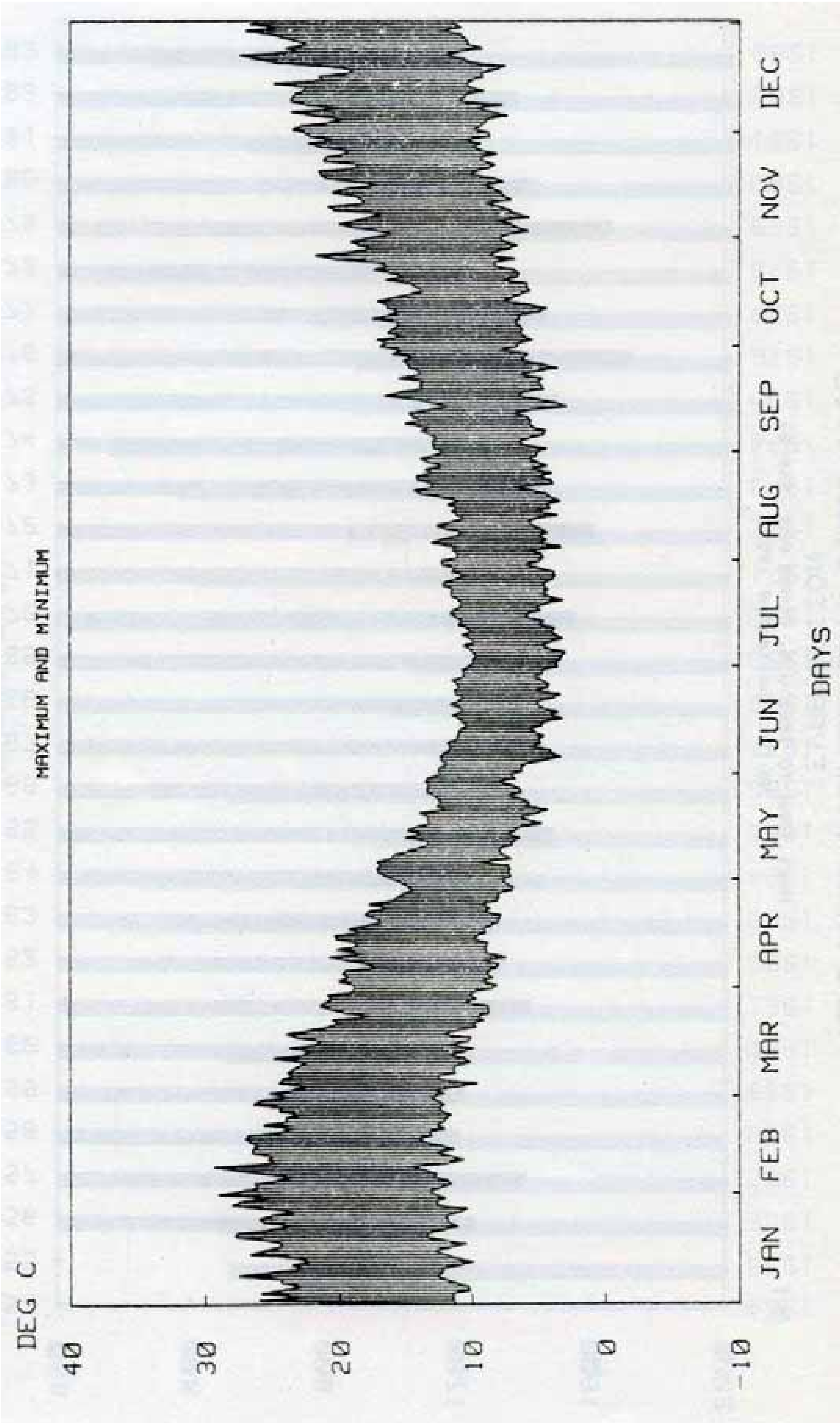

Fig3 – Parwan Temperature Data 1971 to 1983 – Daily average

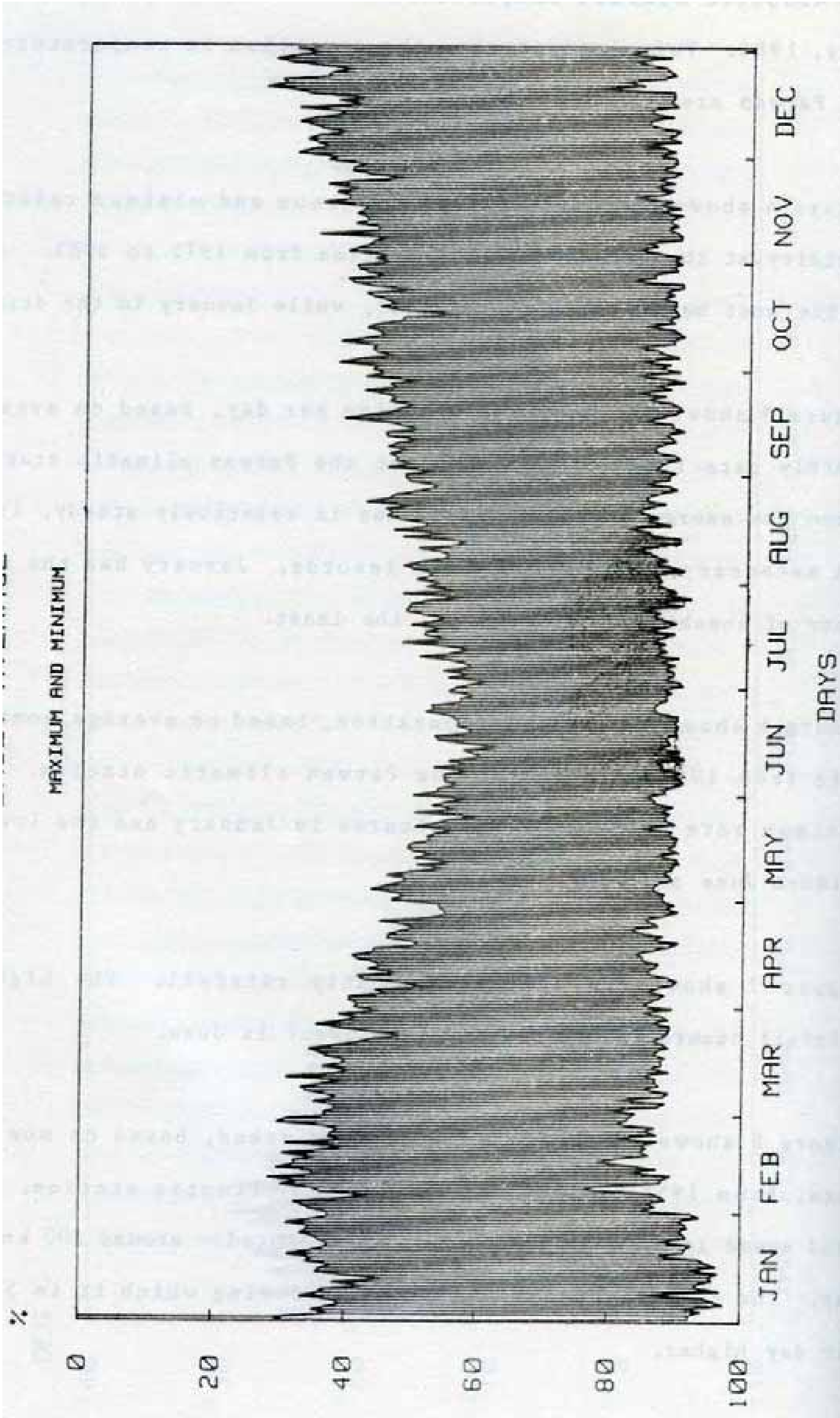

Fig 4 – Parwan Humidity 1971 to 1983 – Daily Average

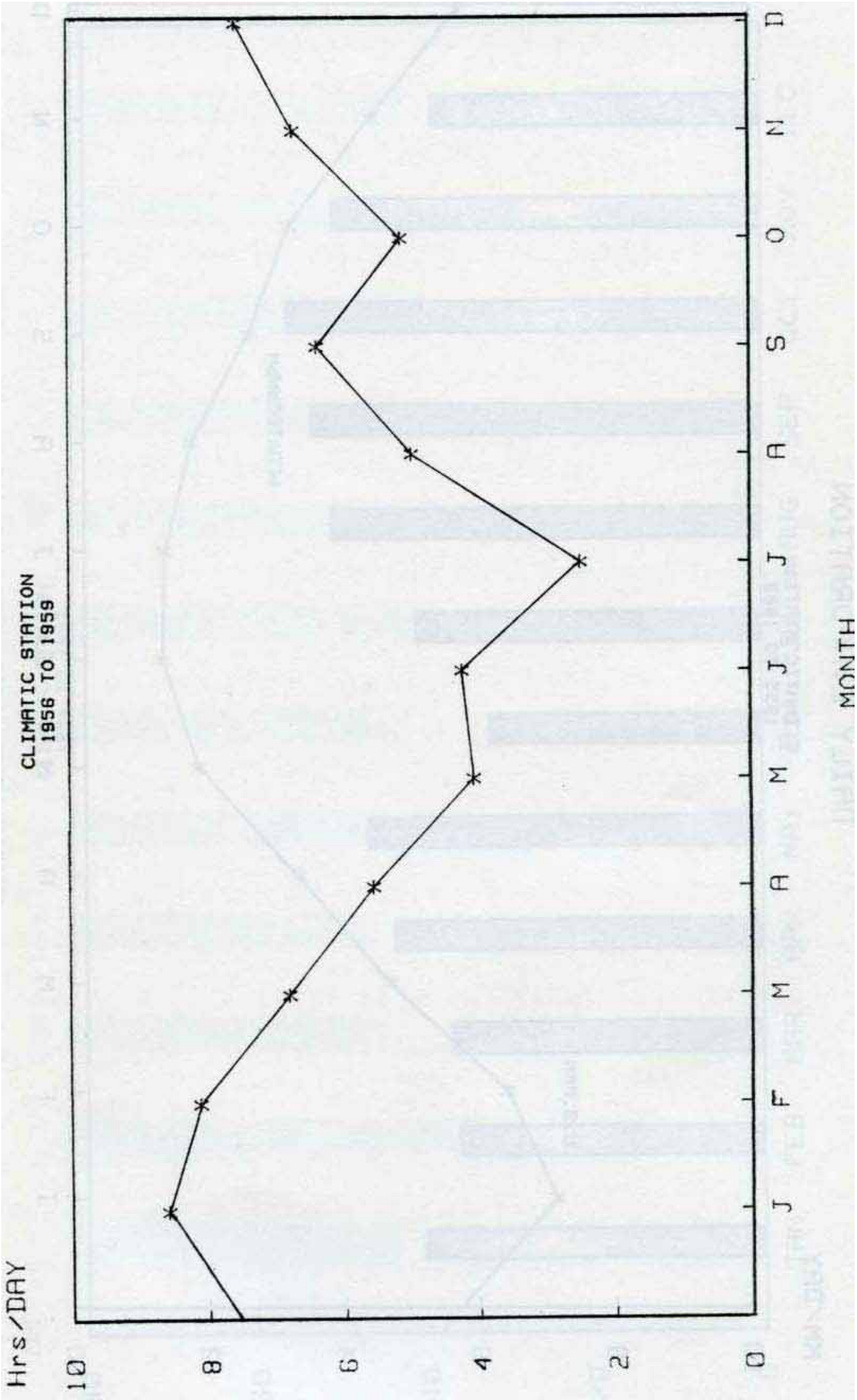

Fig 5 – Parwan Average Monthly Data – Daily Sunshine Hours

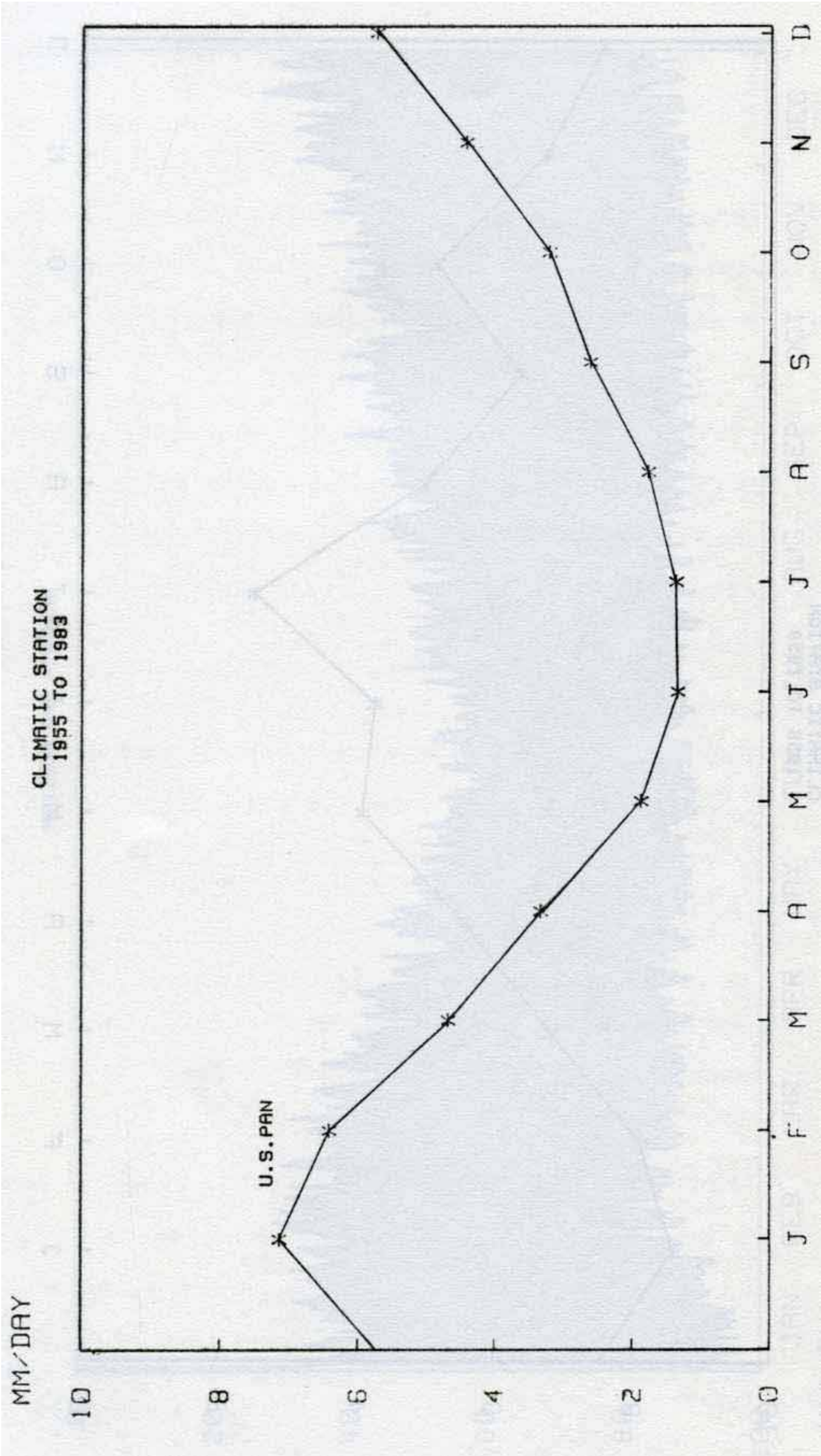

Fig 6 – Parwan Average Monthly Data – Daily Evaporation

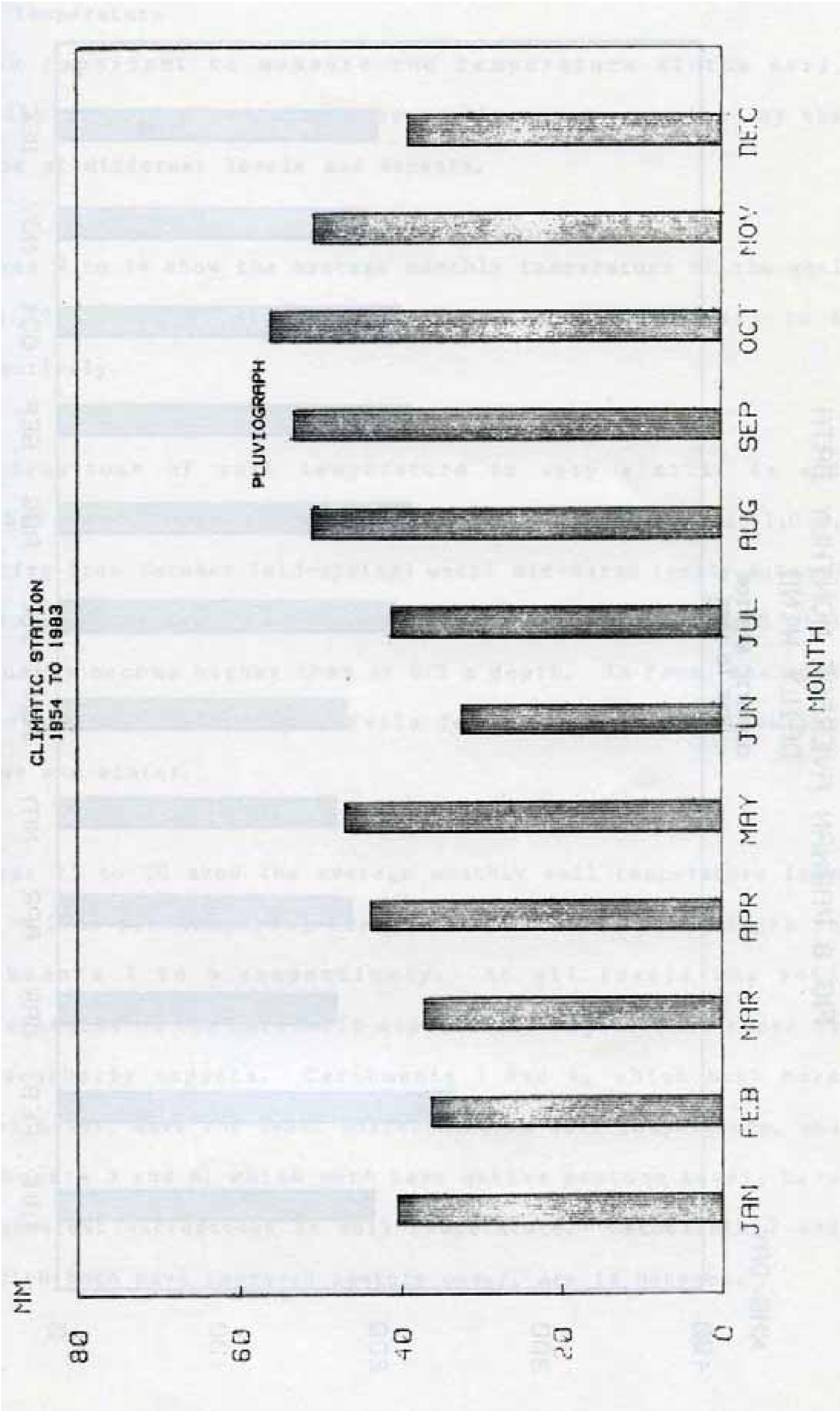

Fig 7 – Parwan Average Monthly Data – Rainfall Monthly Total

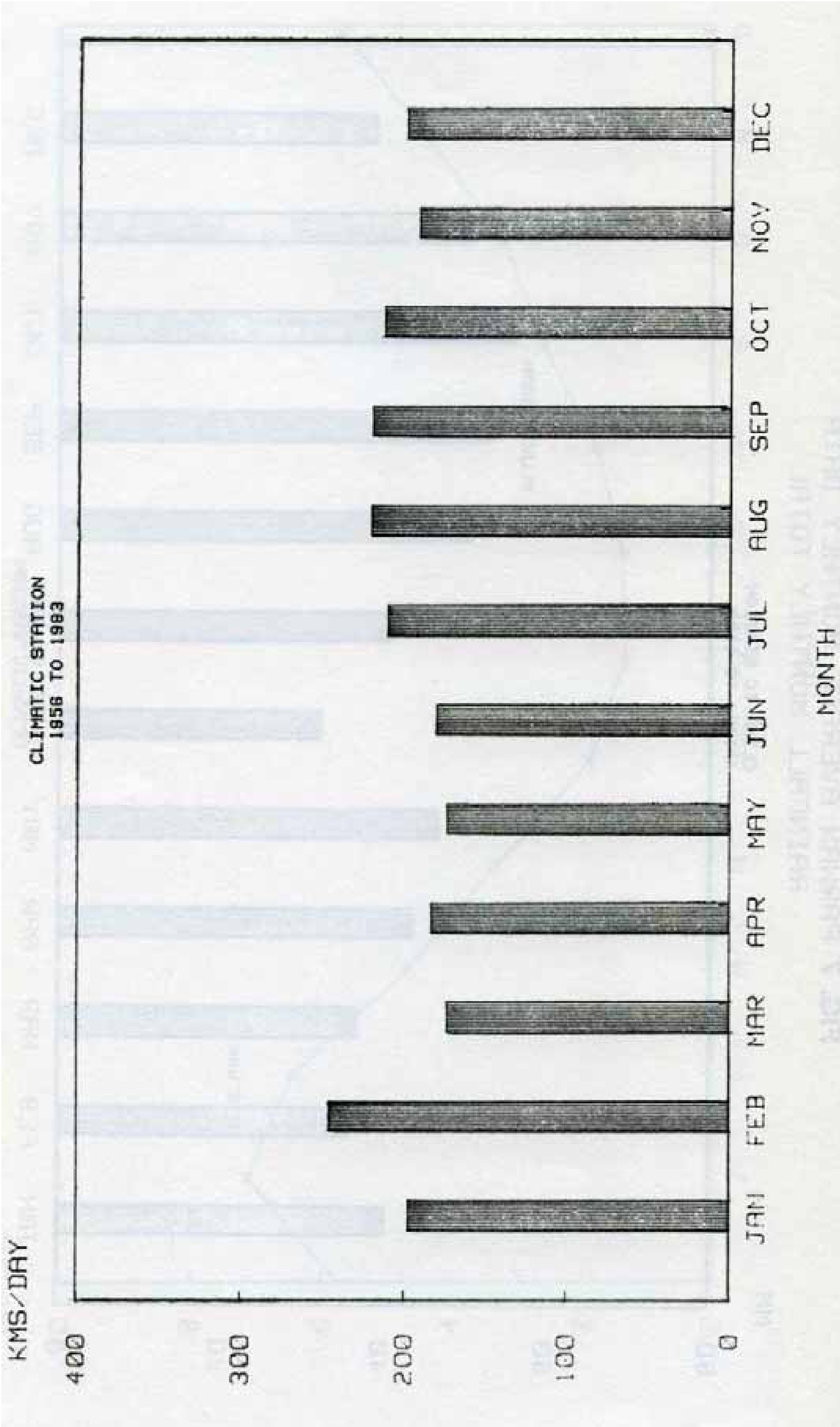

Fig 8 – Parwan Average Monthly Data – Daily Wind

8. Soil Temperature

It is important to measure the temperature of the soil, particularly if we want to compare the energy received by the ground different levels and aspects.

Figures 9 to 14 show the average monthly temperature of the soil from 1974 to 1983 at 0.5 m and 1.0 m of catchments 1 to 6 respectively.

The behaviour of soil temperature is very similar in all catchments. It is normally higher at 0.5 m depth than at 1.0 m, starting from October (mid-spring) until mid-March (early autumn) the following year, then the soil temperature at 1.0 m depth will gradually become higher than at 0.5 m depth. In fact, the soil temperature at 0.5 m depth falls faster than at 1.0 m during autumn and winter.

Figures 15 to 20 show the average monthly soil temperature from 1974 – 1983 for comparing aspects at 0.5 m and 1.0 m depth in catchments 1 to 6 respectively. At all levels the soil temperatures on the northerly aspects are higher than those on the southerly aspects. Catchments 1 and 4, which both have forest cover, have the least differences in soil temperature, and Catchments 3 and 6, which both have native pasture cover, have the greatest differences in soil temperature. Catchments 2 and 5, which both have improved pasture cover, are in between.

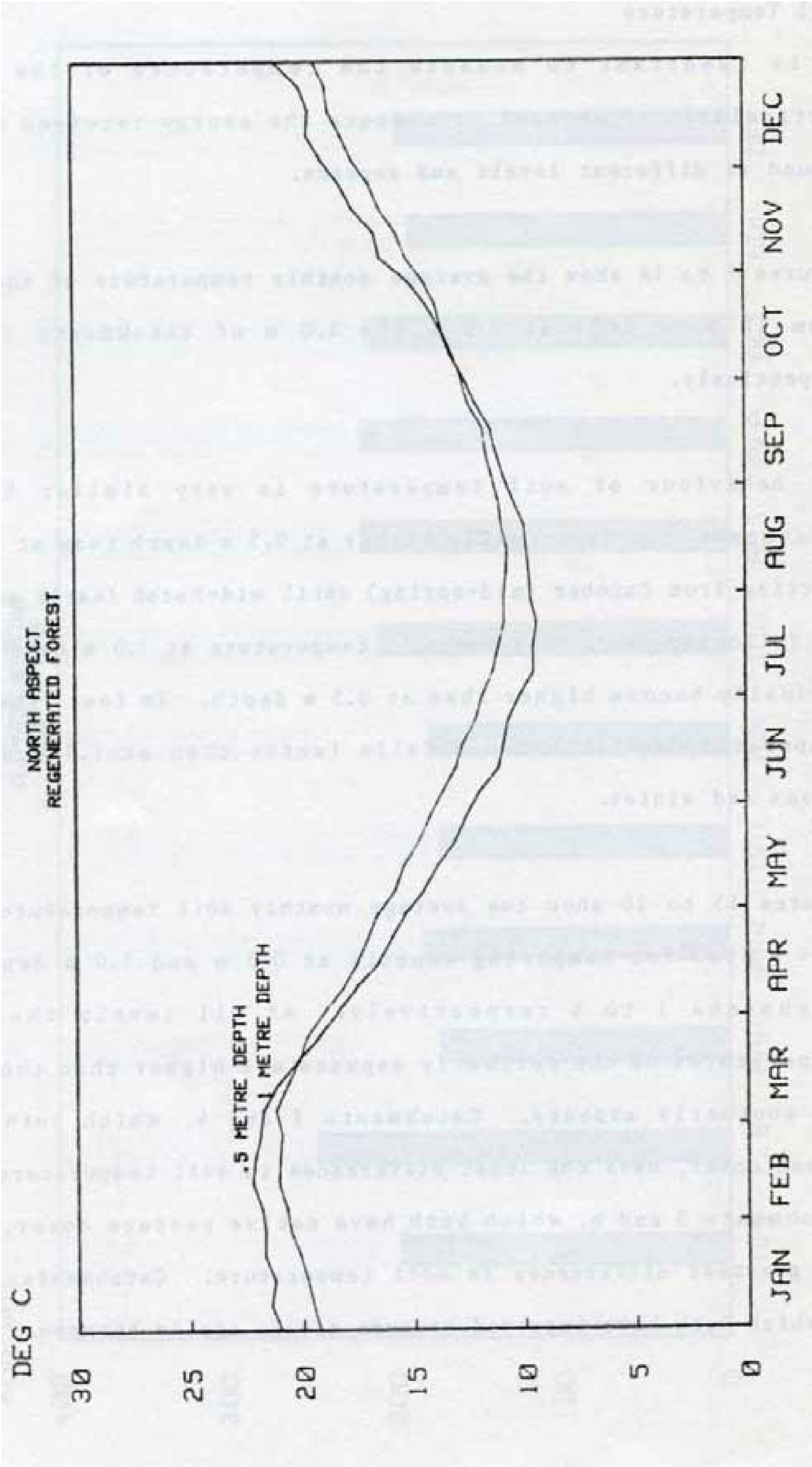

Fig 9 – Parwan Soil Temperatures 1974 to 1983 – Catchment 1

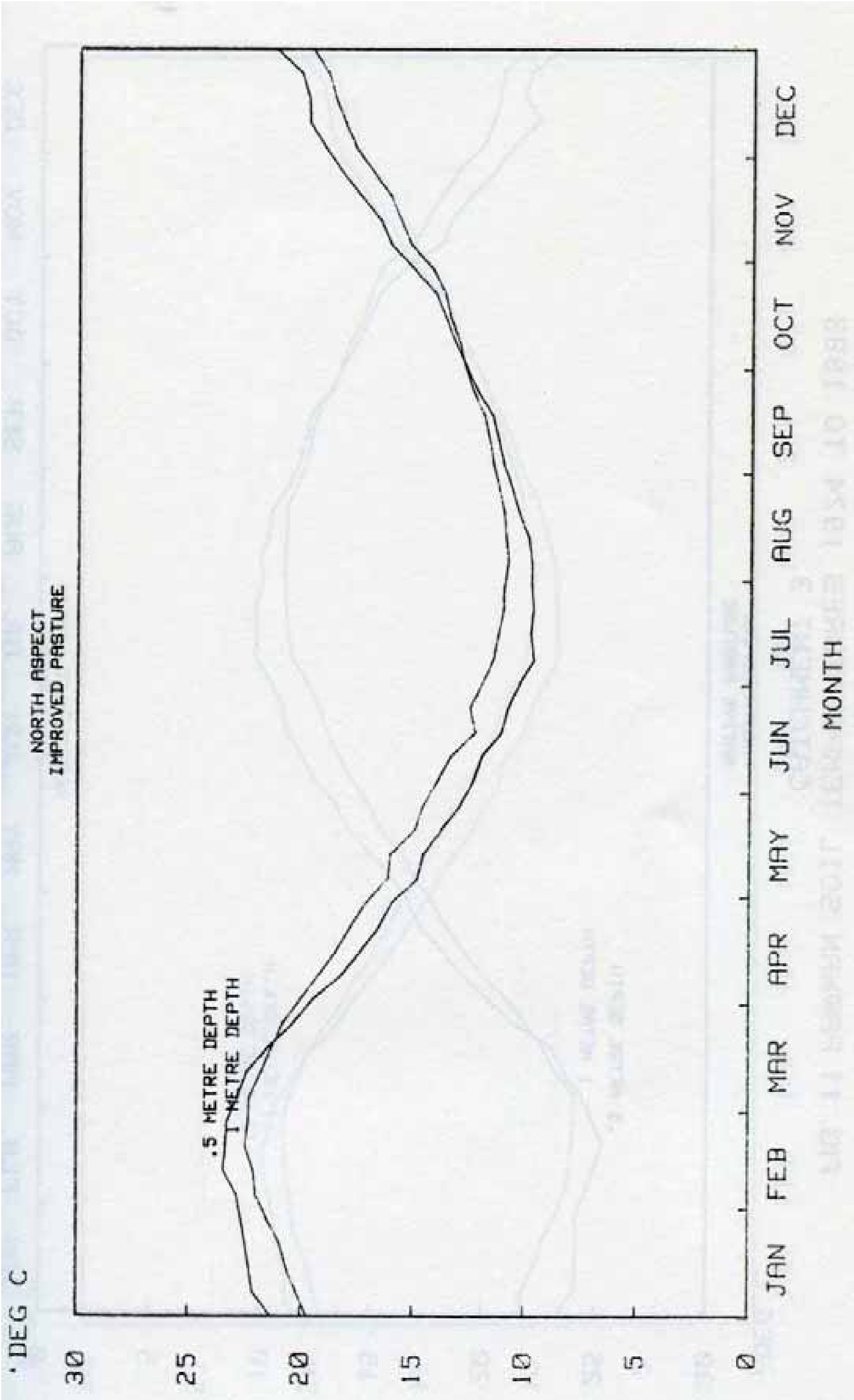

Fig 10 – Parwan Soil Temperatures 1974 to 1983 – Catchment 2

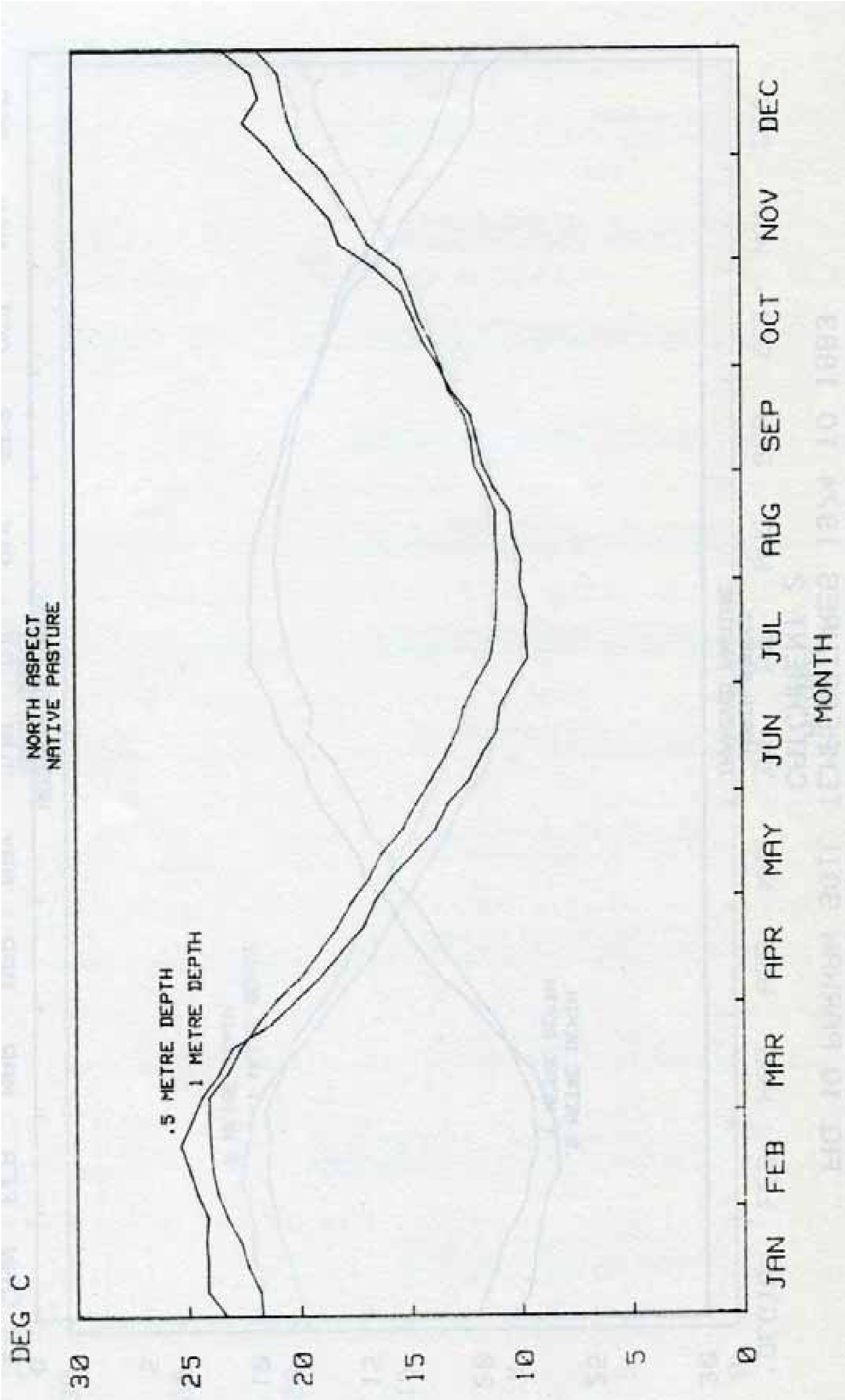

Fig 11 – Parwan Soil Temperatures 1974 to 1983 – Catchment 3

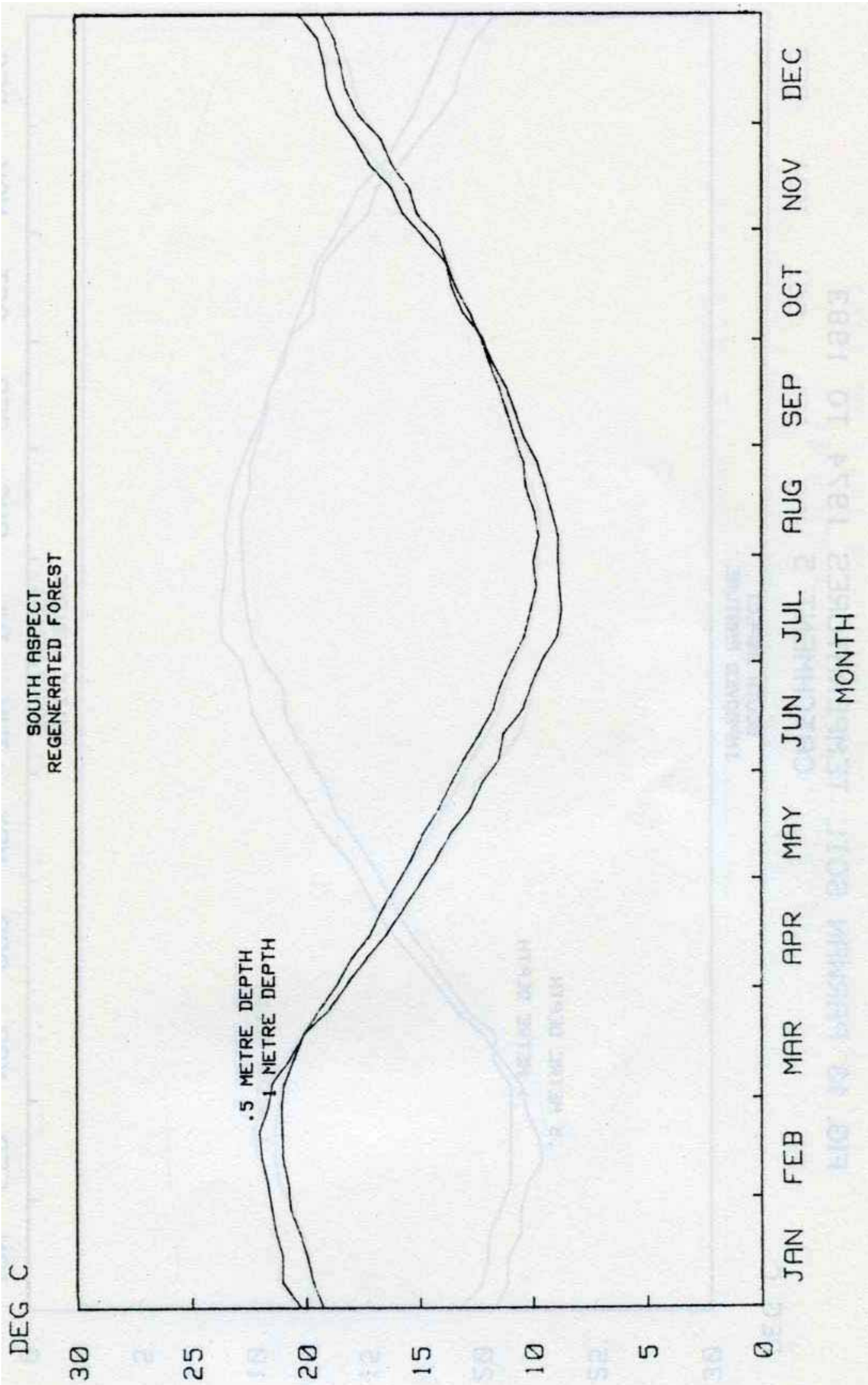

Fig 12 – Parwan Soil Temperatures 1974 to 1983 – Catchment 4

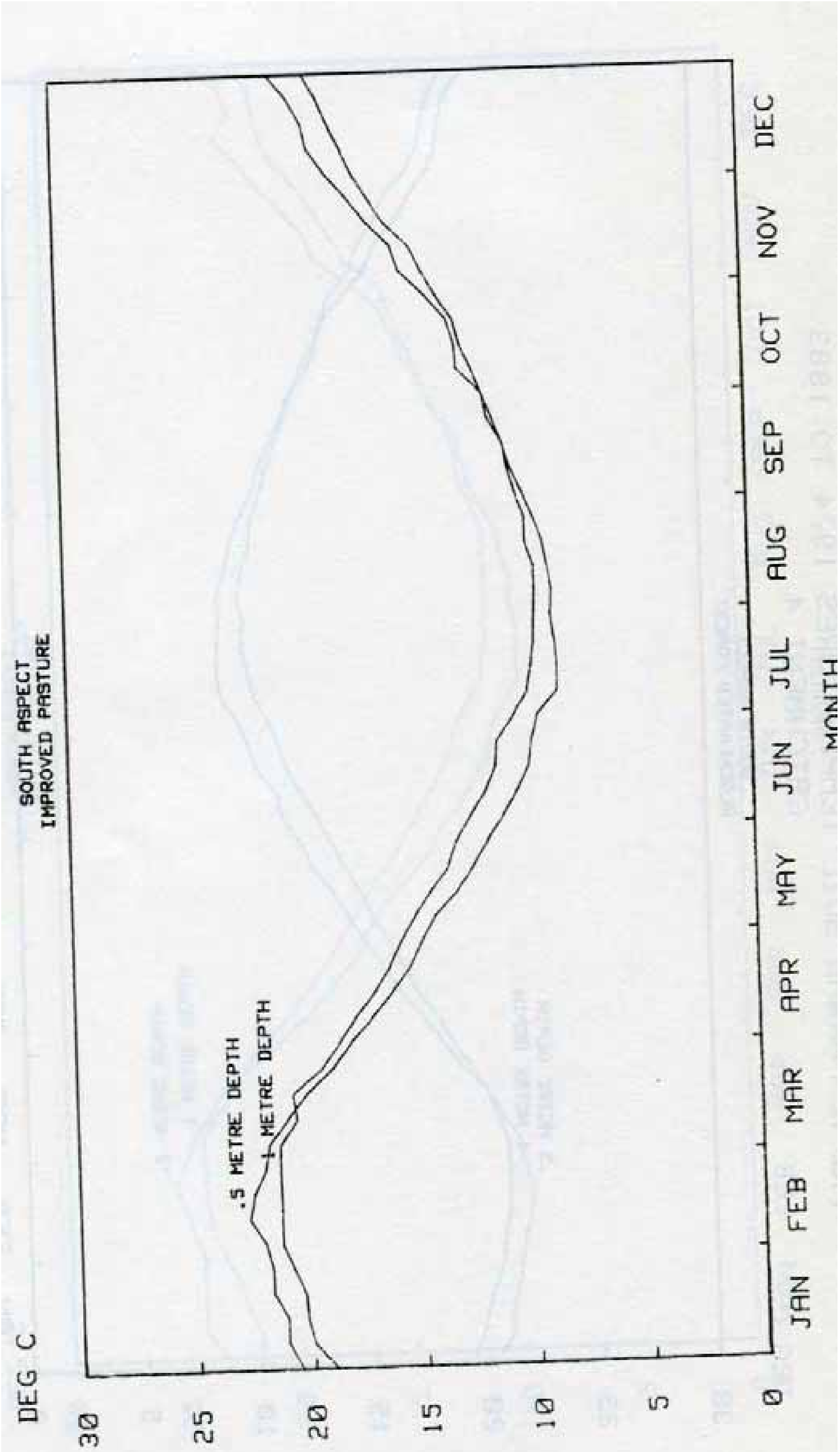

Fig 13 – Parwan Soil Temperatures 1974 to 1983 – Catchment 5

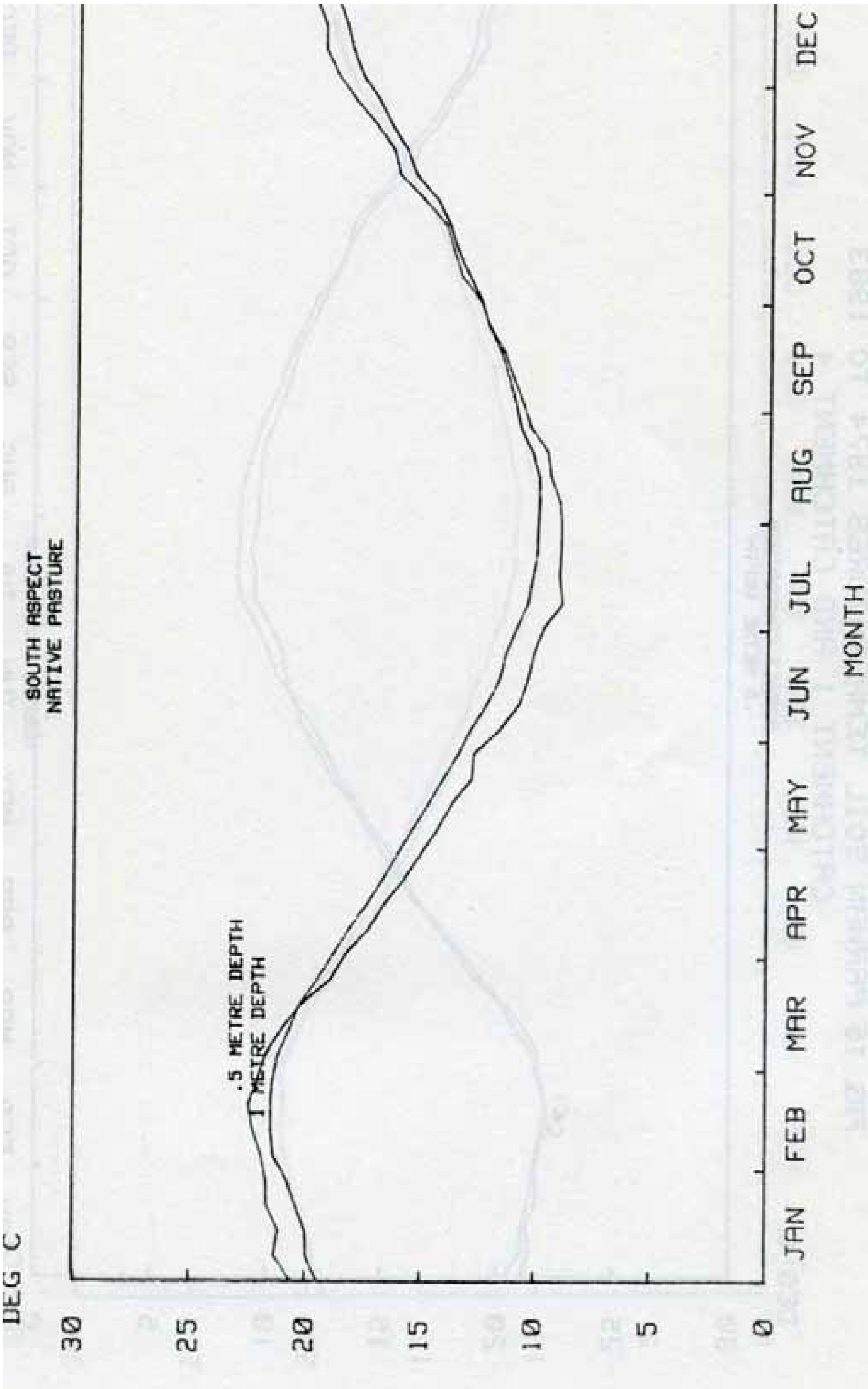

Fig 14 – Parwan Soil Temperatures 1974 to 1983 – Catchment 6

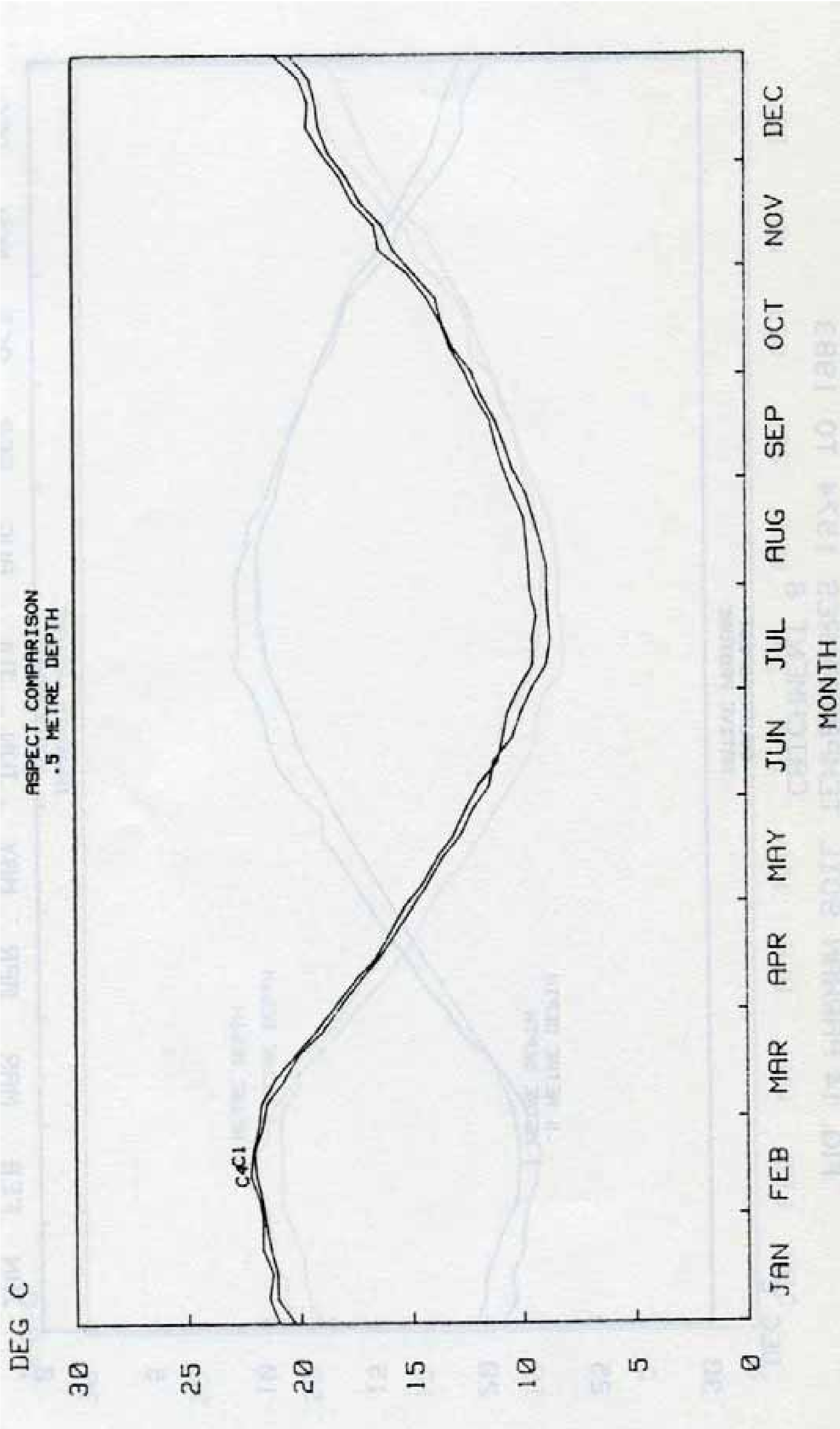

Fig 15 – Parwan Soil Temperatures 1974 to 1983 – Catchment 1 and Catchment 4

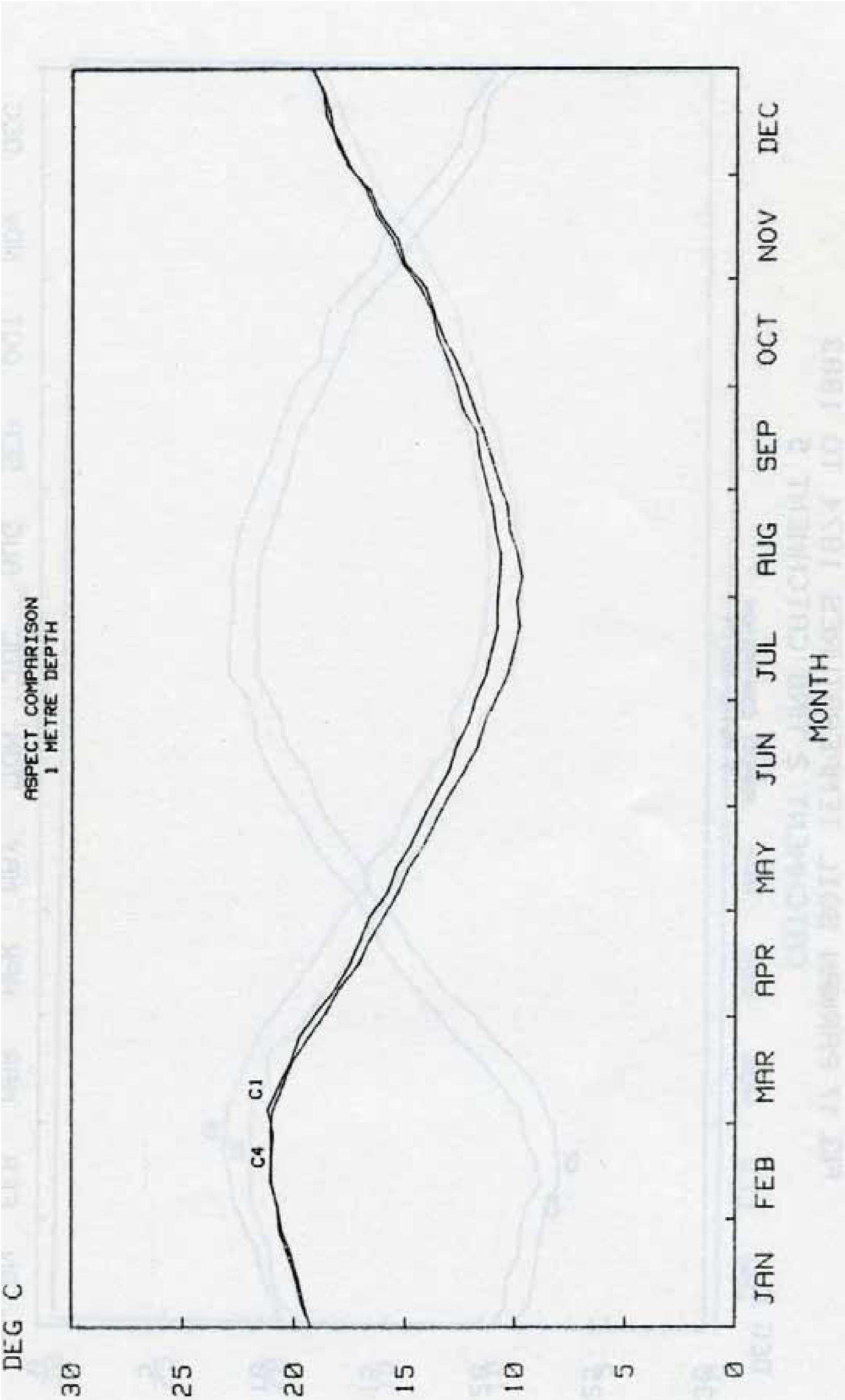

Fig 16 – Parwan Soil Temperatures 1974 to 1983 – Catchment 1 and Catchment 4

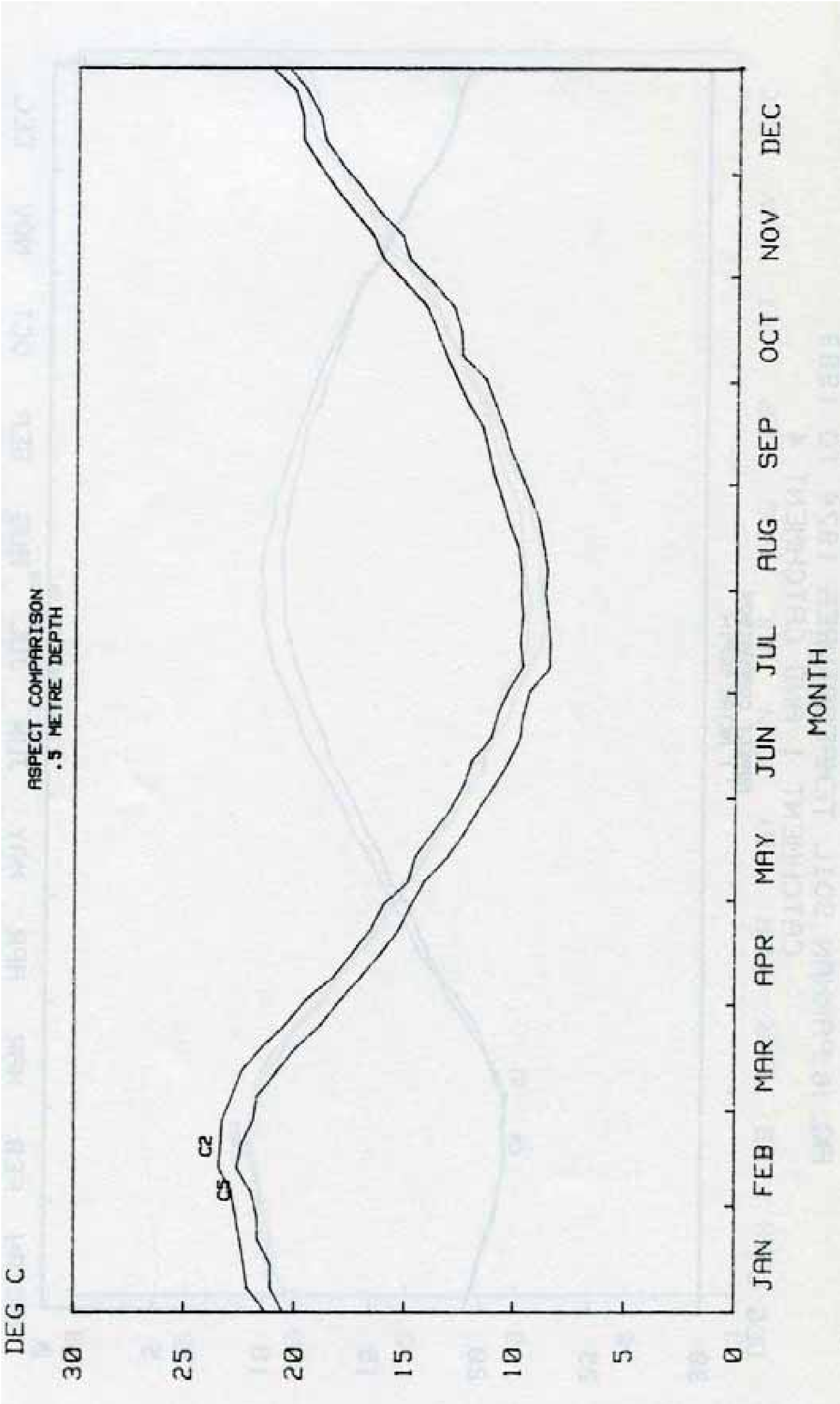

Fig 17 – Parwan Soil Temperatures 1974 to 1983 – Catchment 2 and Catchment 5

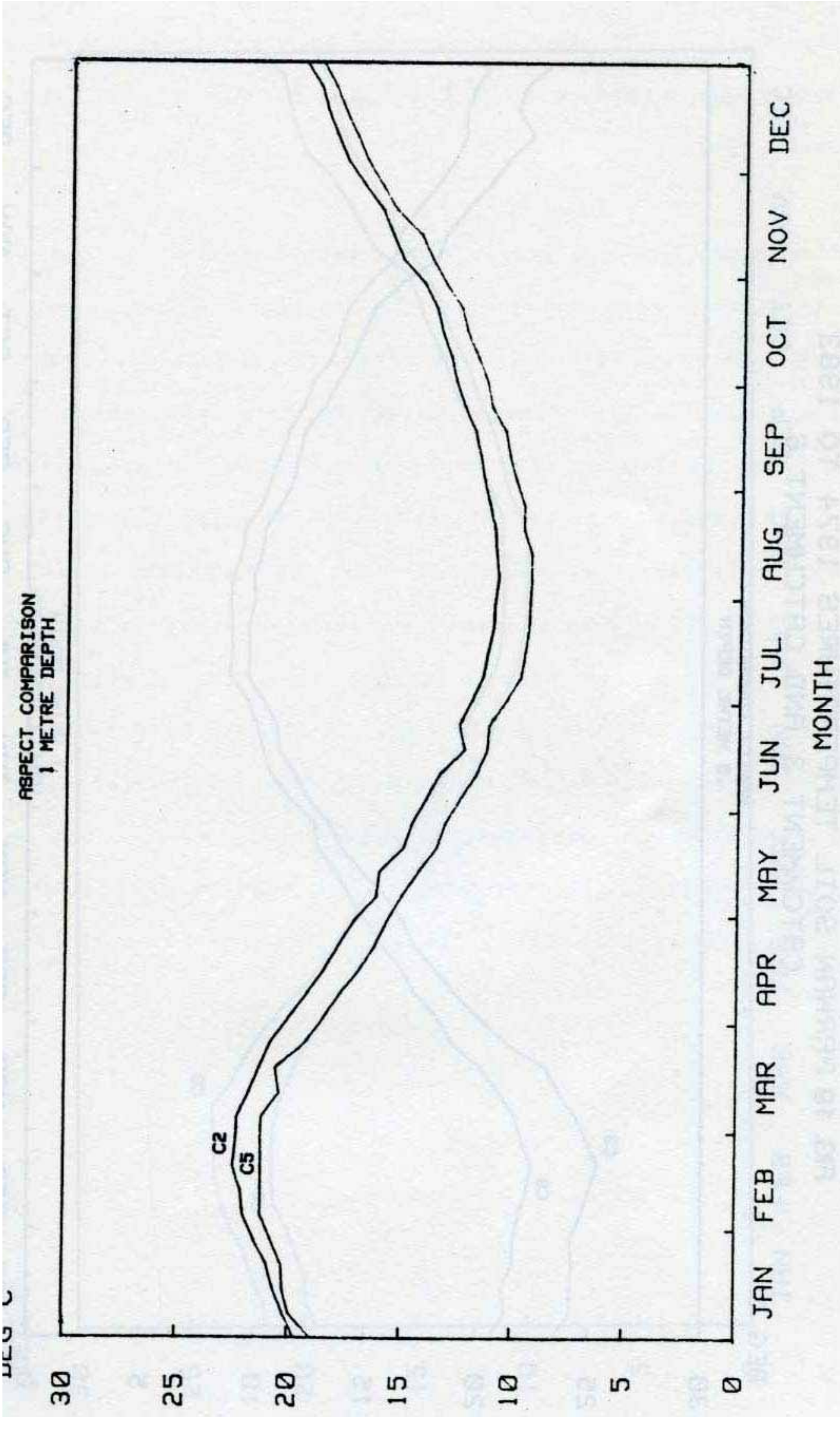

Fig 18 – Parwan Soil Temperatures 1974 to 1983 – Catchment 2 and Catchment 5

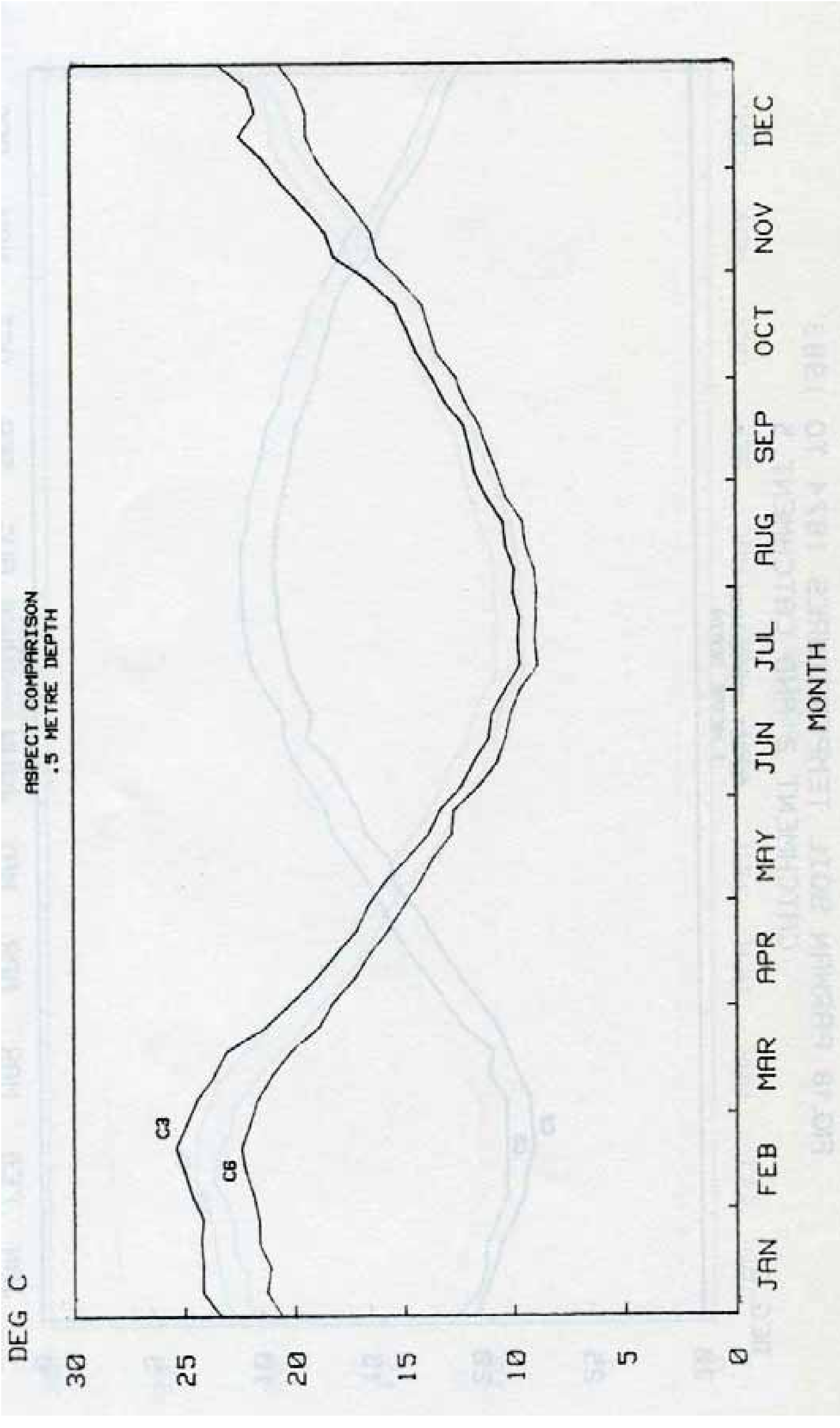

Fig 19 – Parwan Soil Temperatures 1974 to 1983 – Catchment 3 and Catchment 6

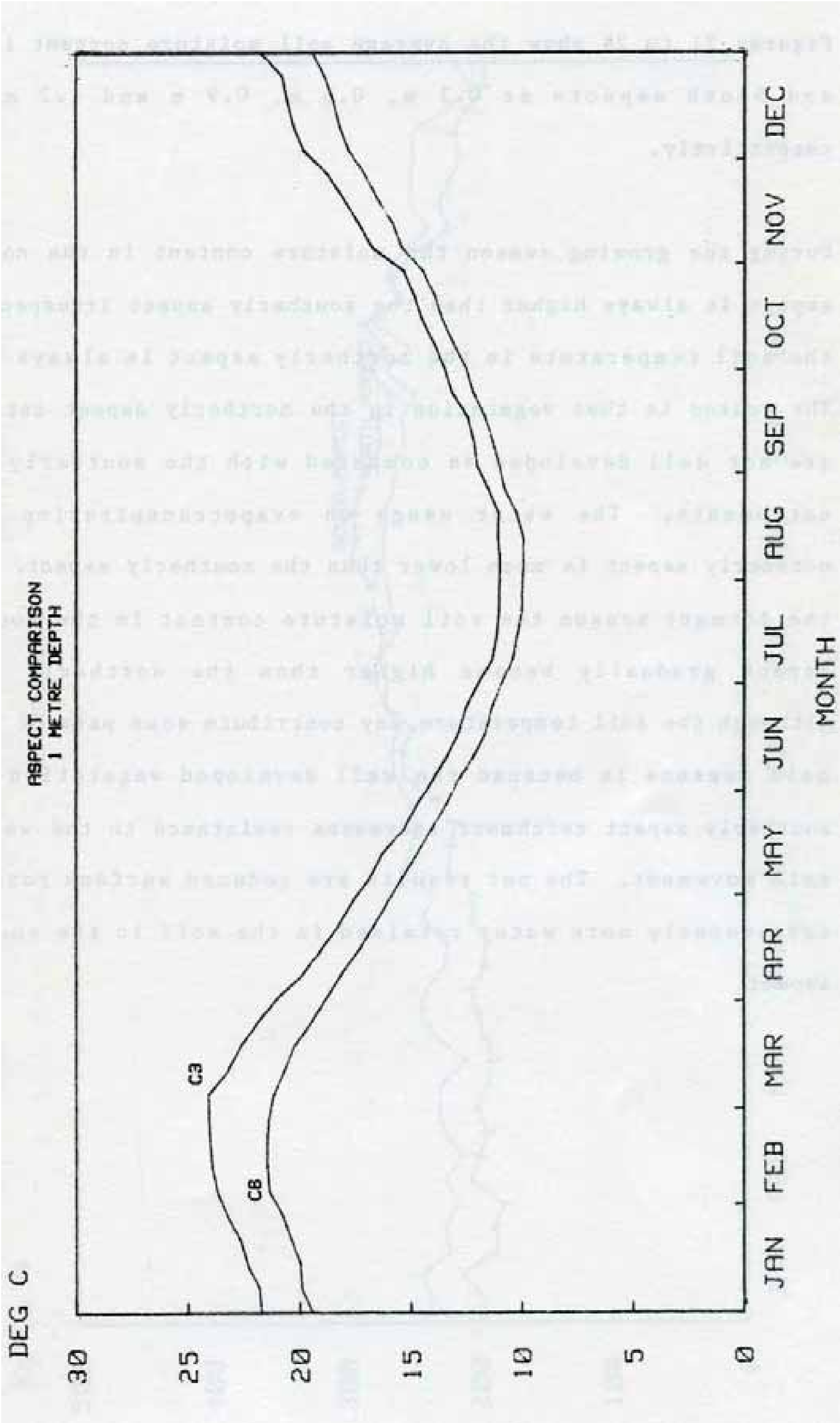

Fig 20 – Parwan Soil Temperatures 1974 to 1983 – Catchment 3 and Catchment 6

7. Soil Moisture

Figures 21 to 24 show the average soil moisture content in North and South aspects at 0.3 m, 0.6 m, 0.9 m and 1.2 m depth respectively.

During the growing season the moisture content in the northerly aspect is always higher than the southerly aspect irrespectively, the soil temperature in the northerly aspect is always higher. The reason is that vegetation in the northerly aspect catchments are not well developed as compared with the southerly aspect catchments. The water usage on evaportranspiration in the northerly aspect is much lower than the southerly aspect. During the dormant season the soil moisture content in the southerly aspect gradually become higher than the northerly aspect. Although the soil temperature may contribute some part of it, the main reasons is because the well developed vegetation in the southerly aspect catchment increases resistance to the water and soil movement. The net results are reduced surface runoff and consequently more water retained in the soil in the southerly aspect.

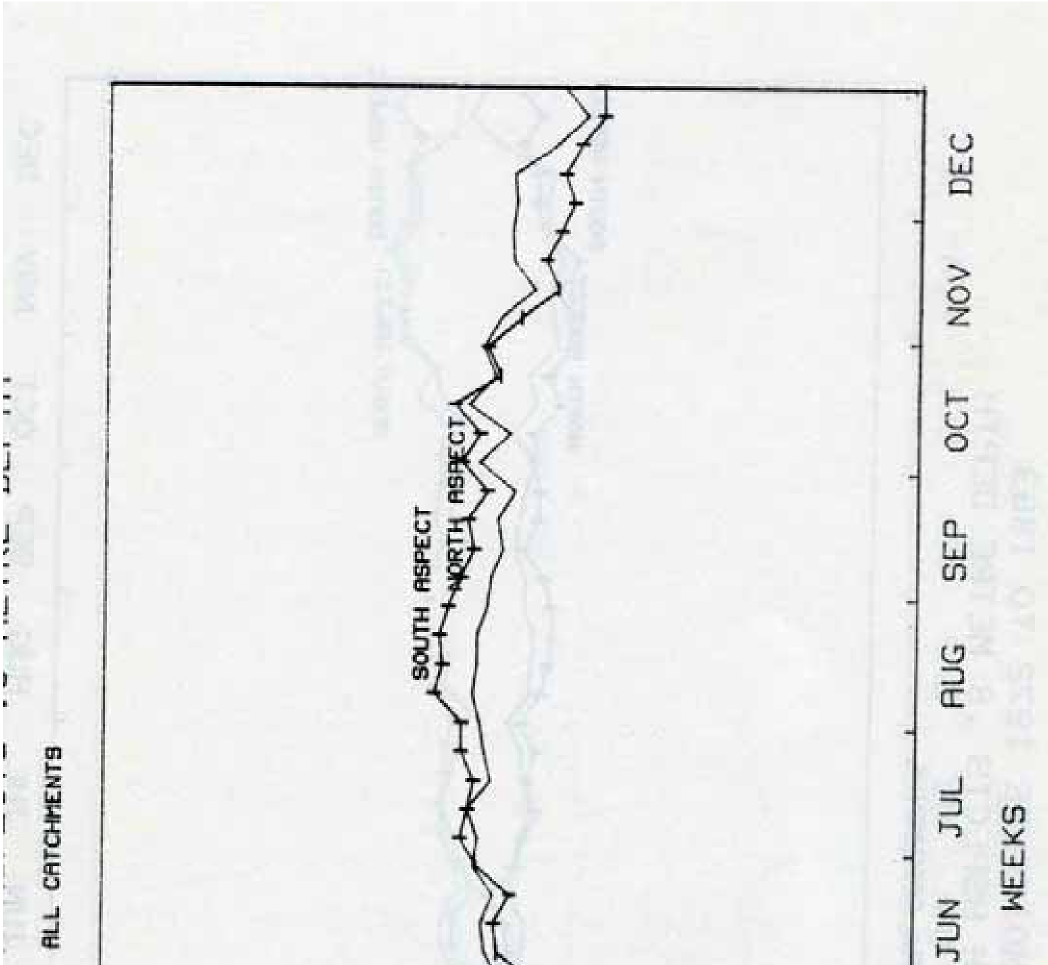

Fig 21 – Parwan Soil Moisture 1972 to 1983 – North and South Aspects 0.3 metre depth

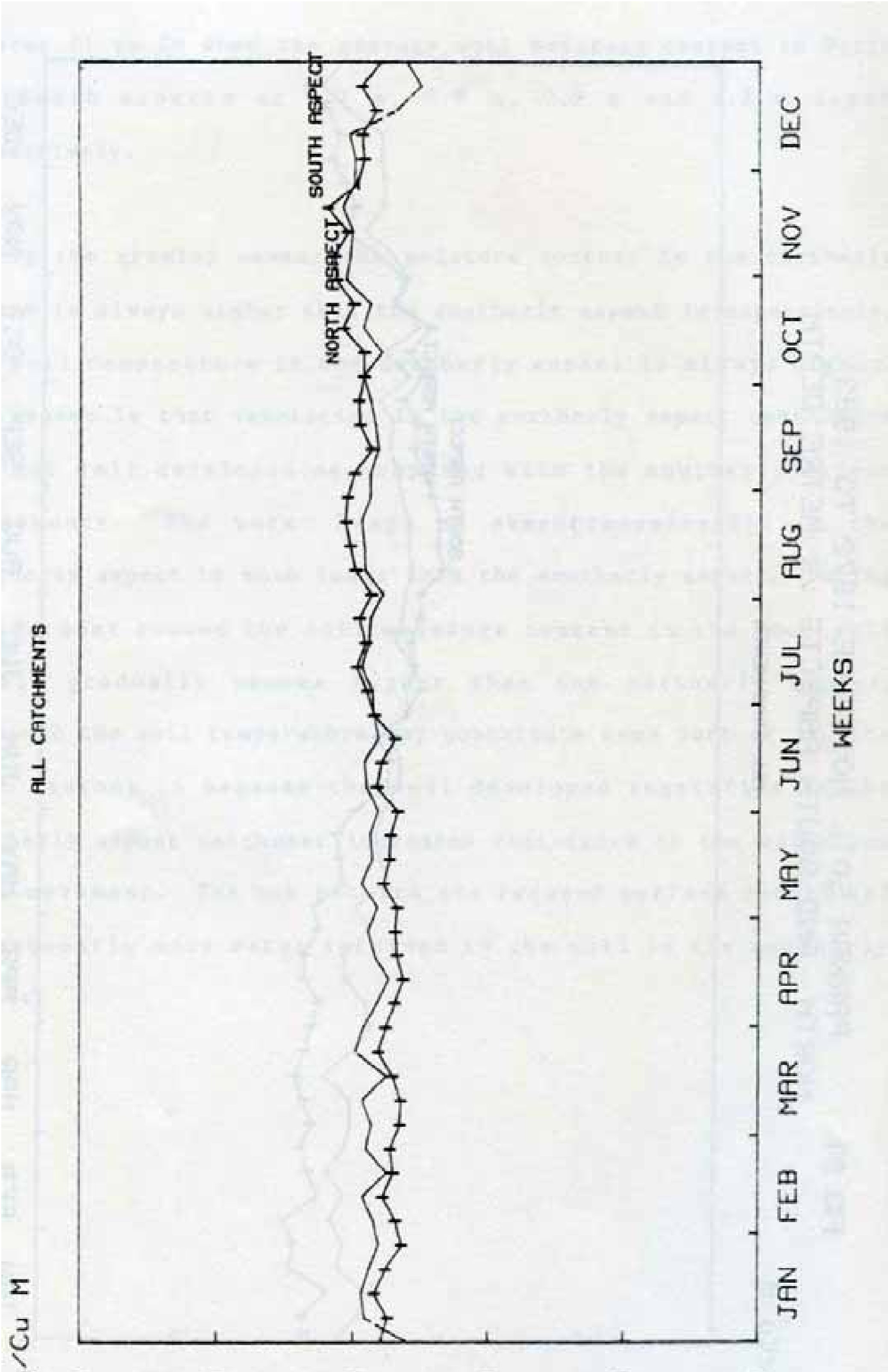

Fig 22 – Parwan Soil Moisture 1972 to 1983 – North and South Aspects 0.6 metre depth

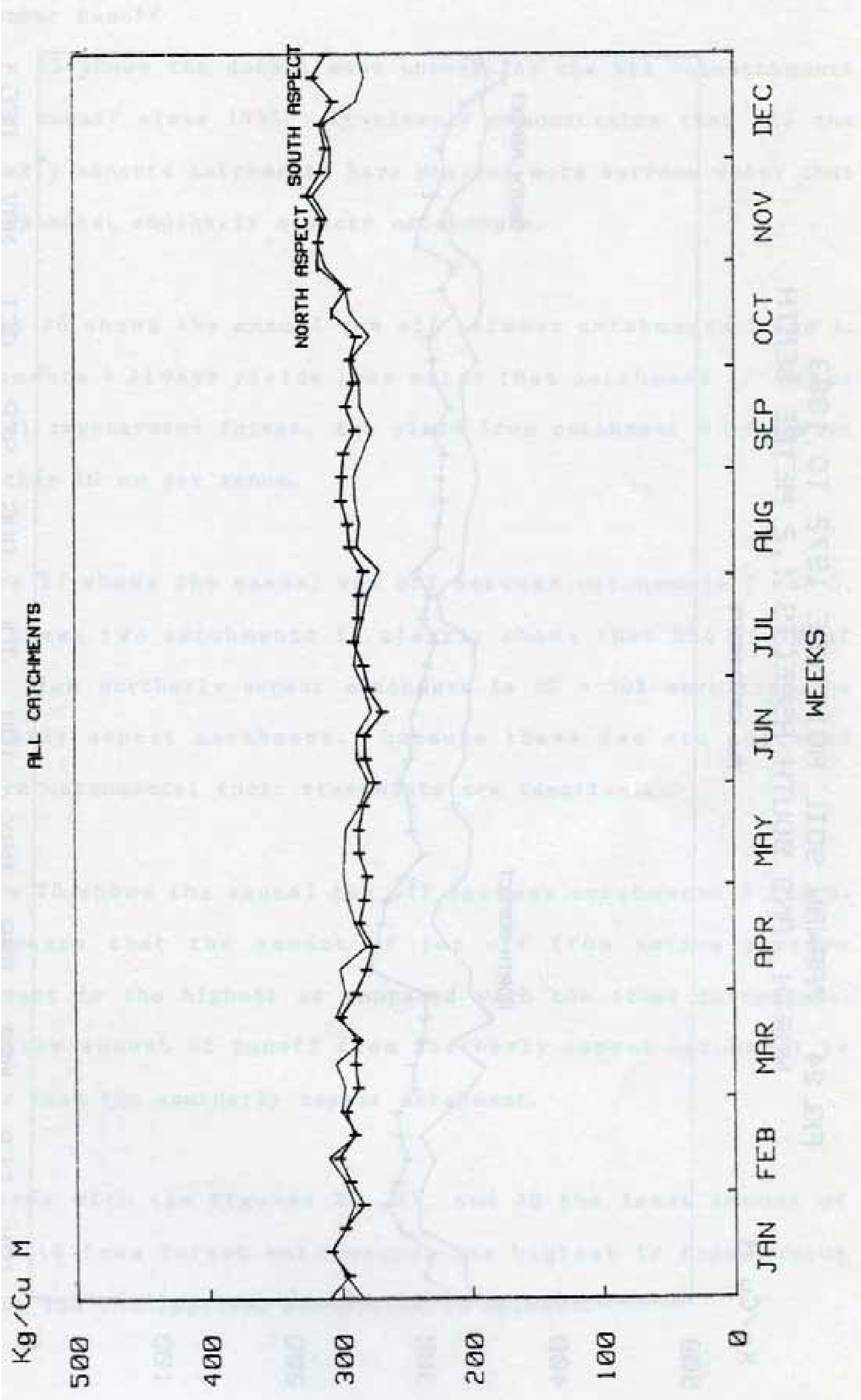

Fig 23 – Parwan Soil Moisture 1972 to 1983 – North and South Aspects 0.9 metre depth

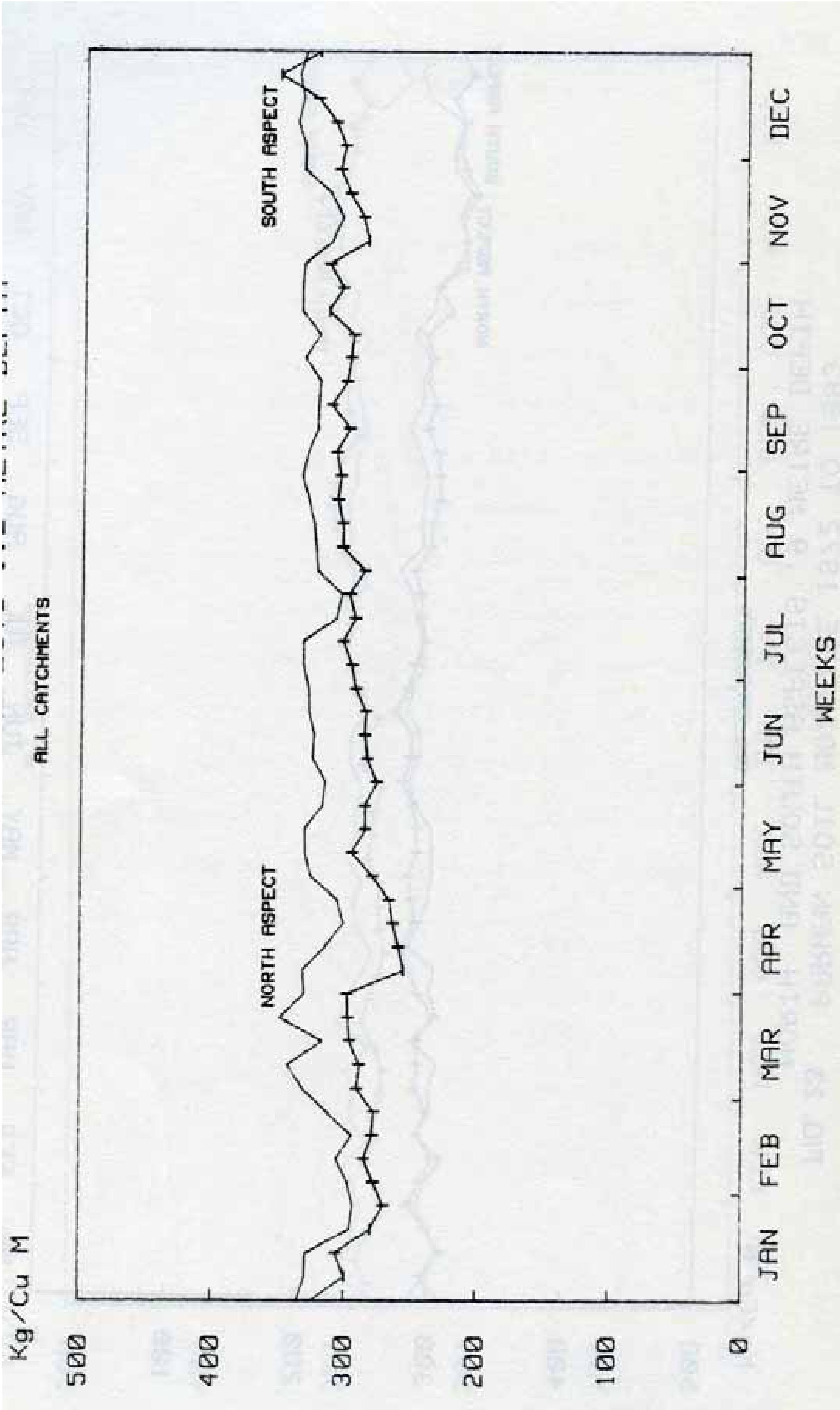

Fig 24 – Parwan Soil Moisture 1972 to 1983 – North and South Aspects 1.2 metre depth

8. Catchment Runoff

Figure 25 shows the double mass curves for the six subcatchments annual runoff since 1955. It clearly demonstrates that all the northerly aspects catchments have yielded more surface water than correspondent southerly aspects catchments.

Figure 26 shows the annual run off between catchments 1 and 4. Catchments 4 always yields less water than Catchment 1. After natural regenerated forest, the yield from Catchment 4 is always less than 10 mm per annum.

Figure 27 shows the annual run-off between Catchments 2 and 5. From these two catchments it clearly shows that the yield of water from northerly aspect catchment is 20 – 50% more than the southerly aspect catchment. Because these two are improved pasture catchments; their treatments are identical.

Figure 28 shows the annual run-off between Catchments 3 and 6. It appears that the amount of run-off from native pasture catchment is the highest as compared with the other catchments. Again the amount of runoff from northerly aspect catchment is higher than the southerly aspect catchment.

Compared with the figures 26, 27 and 28 the least amount of run-off is from forest catchments, the highest is from native pasture and the improved pasture is in between.

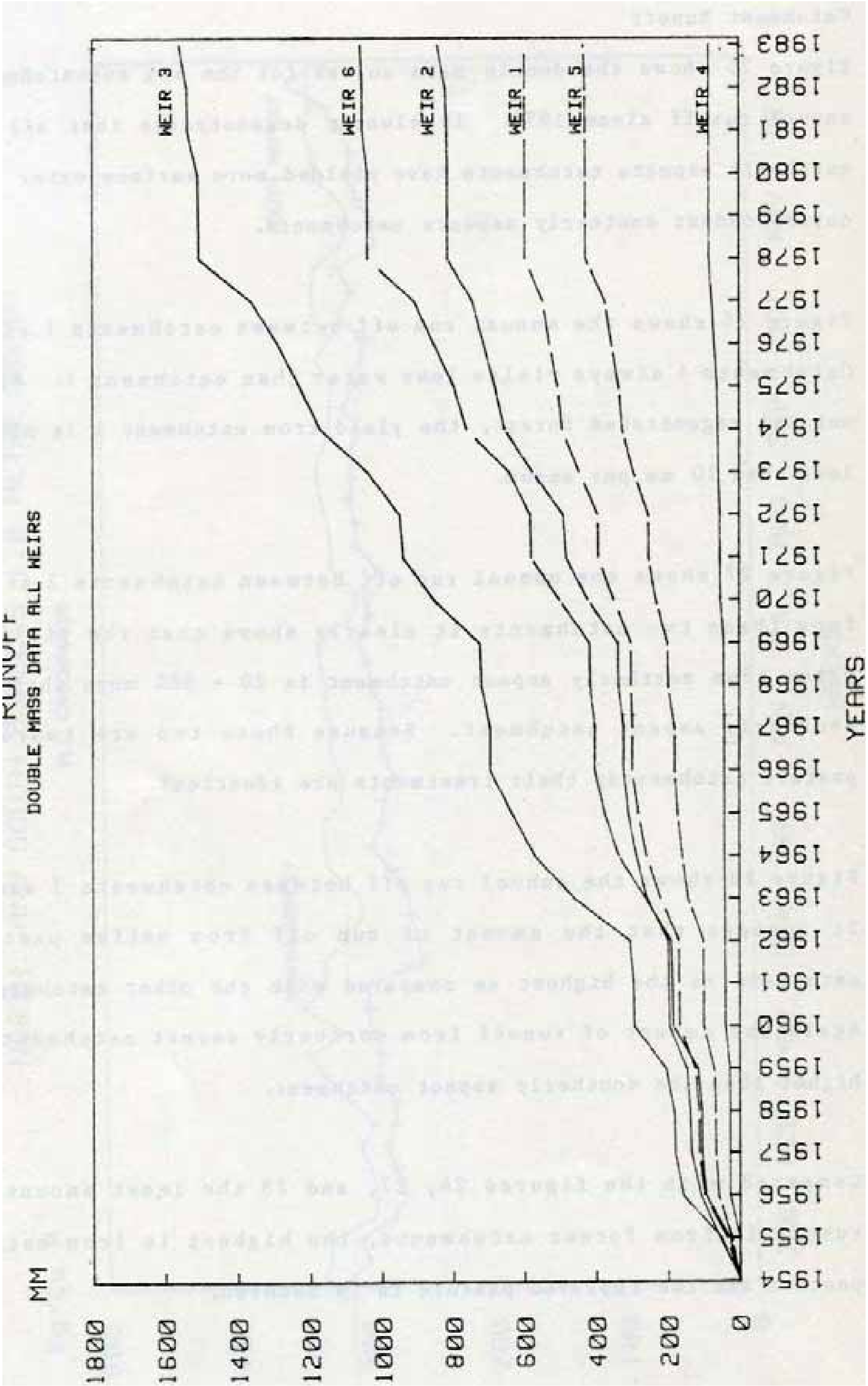

Fig 25 – Parwan Annual Data since 1955 – Run-off

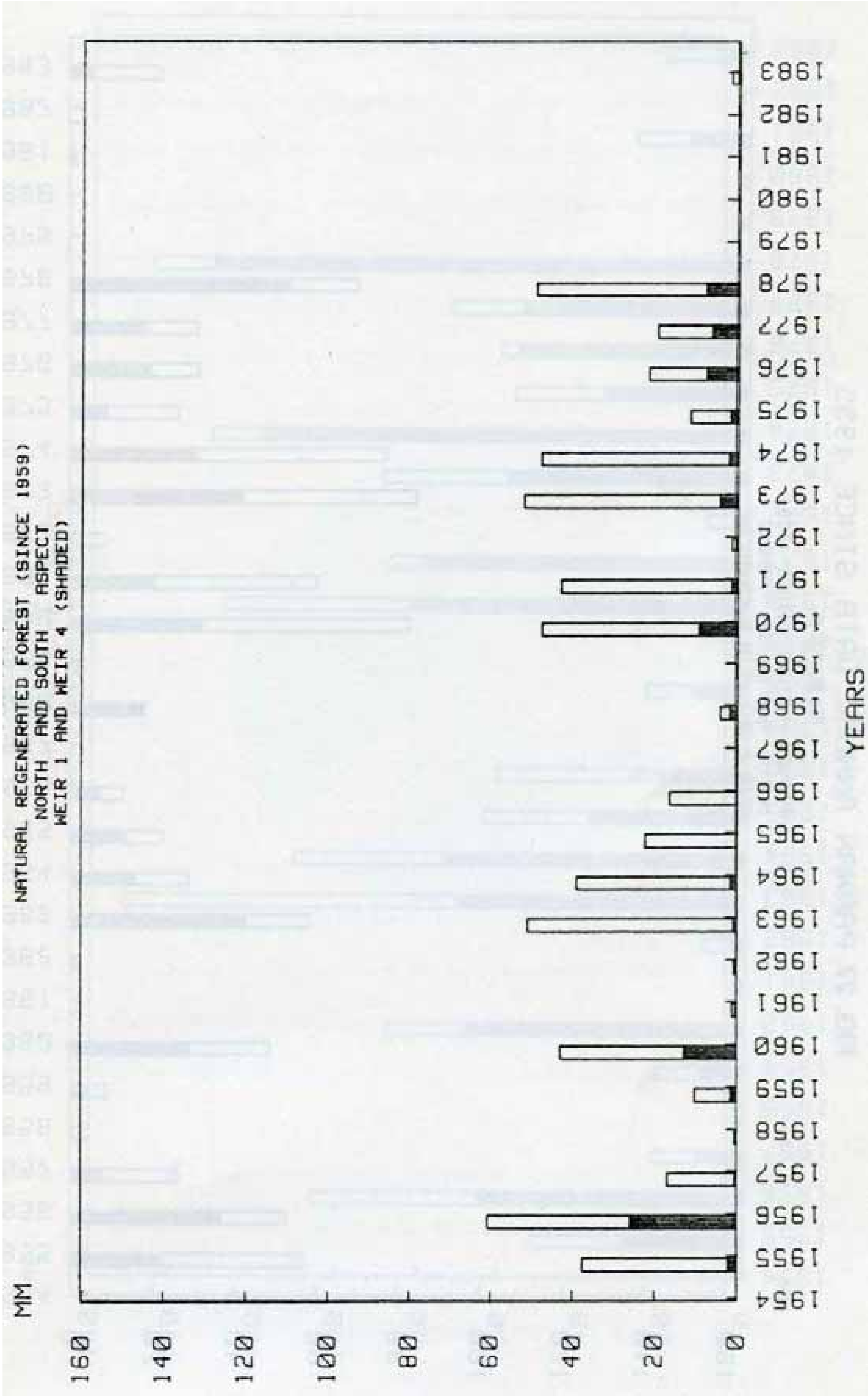

Fig 26 – Parwan Annual Data since 1955 – Run-off

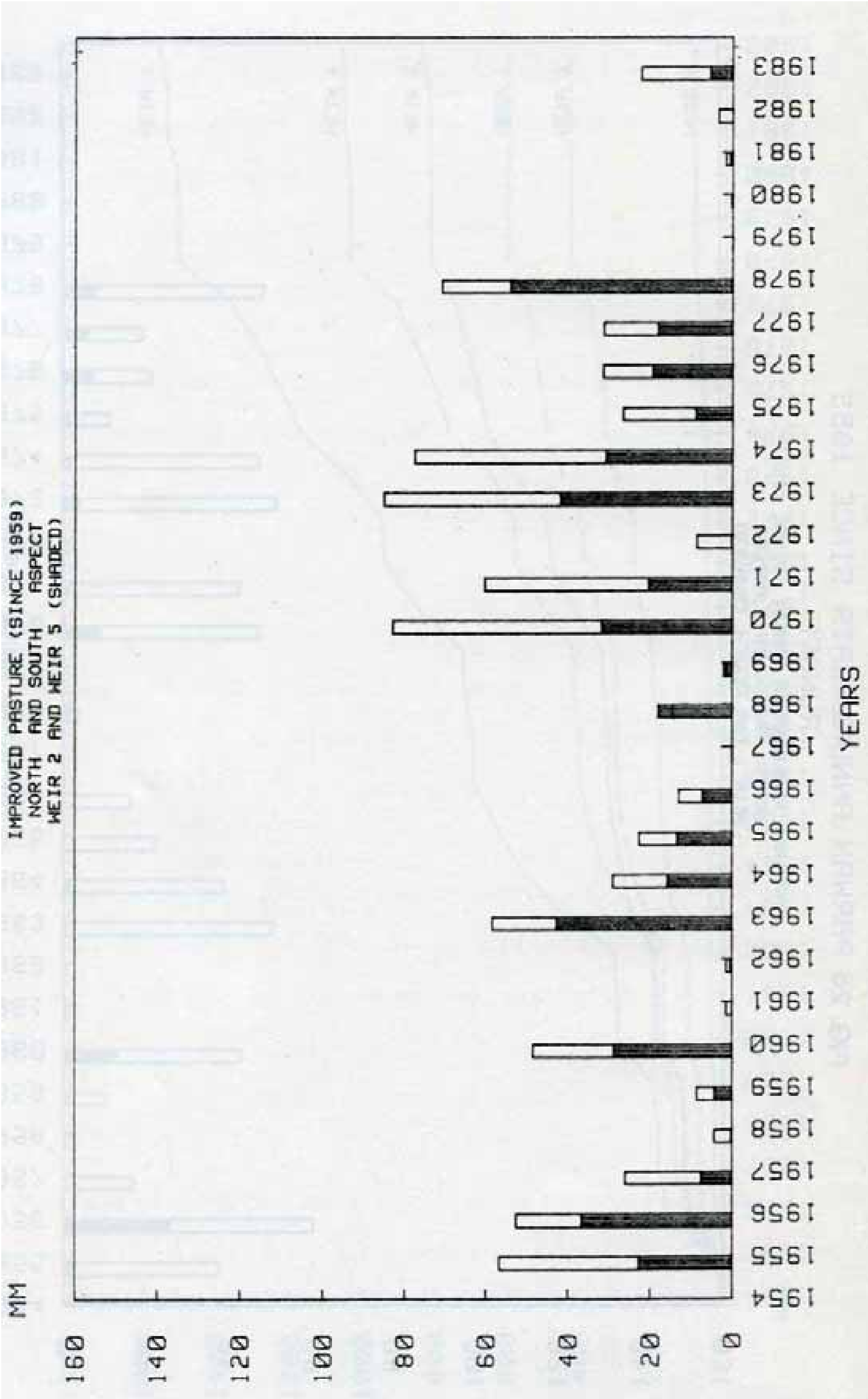

Fig 27 – Parwan Annual Data since 1955 – Run-off

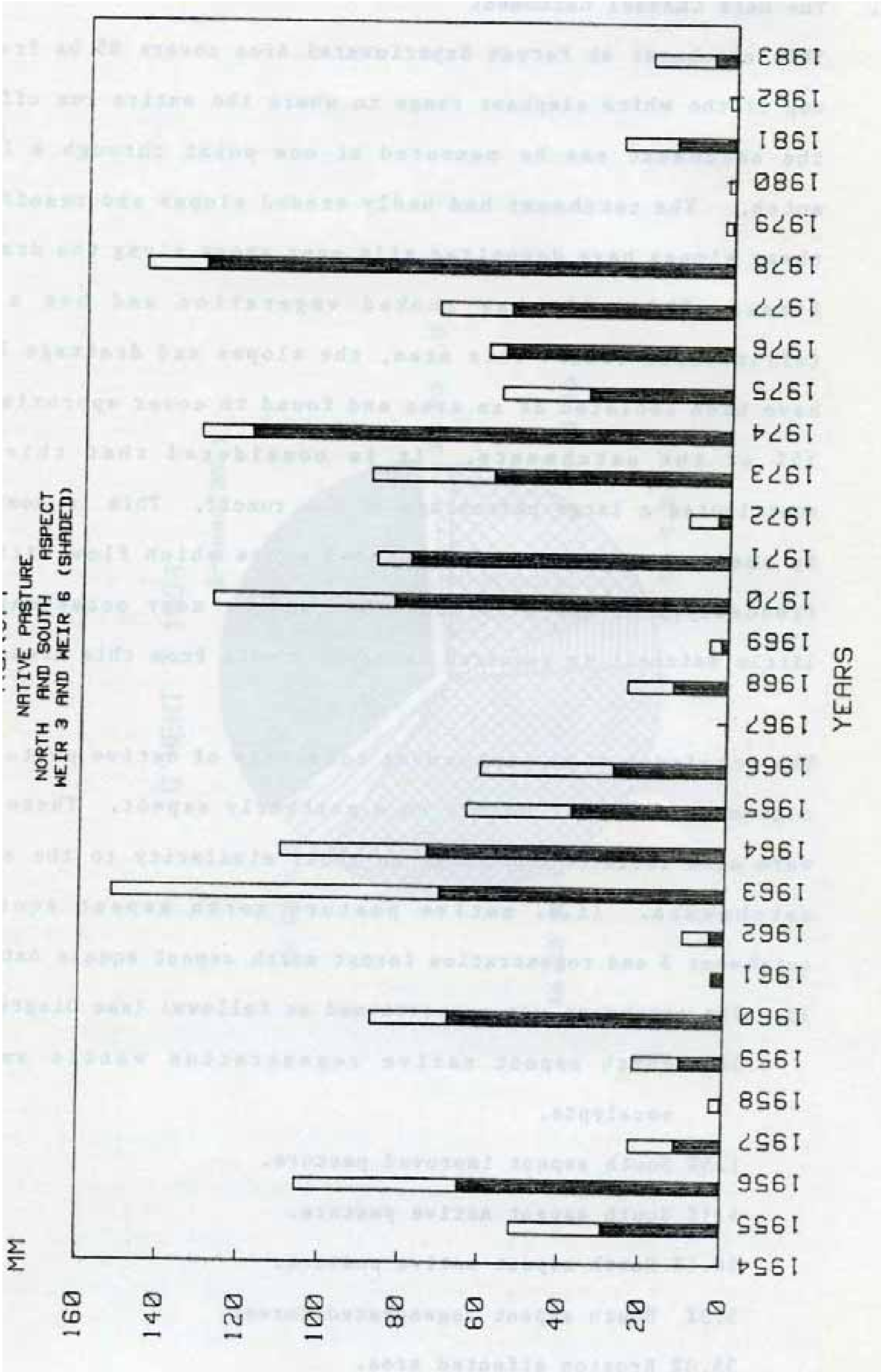

Fig 28 – Parwan Annual Data since 1955 – Run-off

9. The Main Channel Catchment

This catchment at Parwan Experimental Area covers 85 ha from the top of the white elephant range to where the entire run-off from the catchment can be measured at one point through at 120^{o} V notch. The catchment had badly eroded slopes and run-off from these slopes have deposited silt over areas along the drainage lines. This silt has choked vegetation and has a poor infiltration rate. This area, the slopes and drainage lines, have been isolated as an area and found to cover approximately 35% of the catchments. It is considered that this area contributes a large percentage of the run-off. This is confirmed by smaller catchment of vegetated plots which flow with less frequency. It has also been observed on many occasions that little rainfall is required to cause run-off from this area.

The remainder of the catchment comprises of native pasture and regenerated forest mainly on a northerly aspect. These areas were also isolated according to their similarity to the smaller catchments. (I.e. native pasture north aspect equals to Catchment 3 and regeneration forest north aspect equals Catchment 1). The catchment was proportioned as follows: (see Diagram 3)

18%	North aspect native regeneration wattle and eucalypts
1.5%	South aspect native pasture
4.1%	South aspect native pasture
36.1%	North aspect native pasture
5.3%	South aspect regenerated forest
35.0%	Erosion effected area.

An empirical equation can be found as follows:

Run-off from erosion = 2.85 (C7 – 0.18C1 – 0.361C3 – 0.053C4 – 0.015C5 – 0041C6) (1)

Where C1 is the amount of run-off from Catchment No. 1 in mm
C2 is the amount of run-off from Catchment No. 2 in mm and so on
C7 is the amount of run-off fro the main channel catchment.

In December 1978, a steel blade V with the same degree was imbedded in the concrete notch in order to overcome a fluctuating zero error caused by irregular silting. Data after this date have been used. The estimated run-off was then isolated and correlated against the rainfall (if rainfall greater than 6 mm). It was found by observation no run-off could be started except the rainfall amount exceeds 6 mm. Sixty two events data have been used to develop the following regression equation.

Erosion Run-off = 0.305 Rainfall – 1.6 (2)

The reliability of equation (2) can be verified by substituting equation (1) into (2) as follows:

$$\text{Rainfall} = \frac{2.85\,(C7 - 0.18C1 - 0.361C3 - 0.053C4 - 0.015C5 - 0.41C6) + 1.6}{0.305} \qquad (3)$$

By using equation (3) it can use the actual catchments 1, 2, 3, 4, 5 and 6 data to predict the rainfall, and then we can compare this predicted amount of rainfall with the actual rainfall. If the two data can be matched well then equation (2) can be used to predict Erosion Runoff from the 85 ha catchment.

Fig 29 shows a linear relationship between predicted and actual rainfall. After having studied twenty three events, a linear regression equation has been established as follows:

$$Y = 1.01x - 1.64 \qquad (4)$$

where y is the predicted rainfall value and x is the actual rainfall value. Although the data are a little bit skewed, the correlation coefficient is equal to 0.94. In conclusion, equation (2) is a useful to predict the amount of erosion run-off.

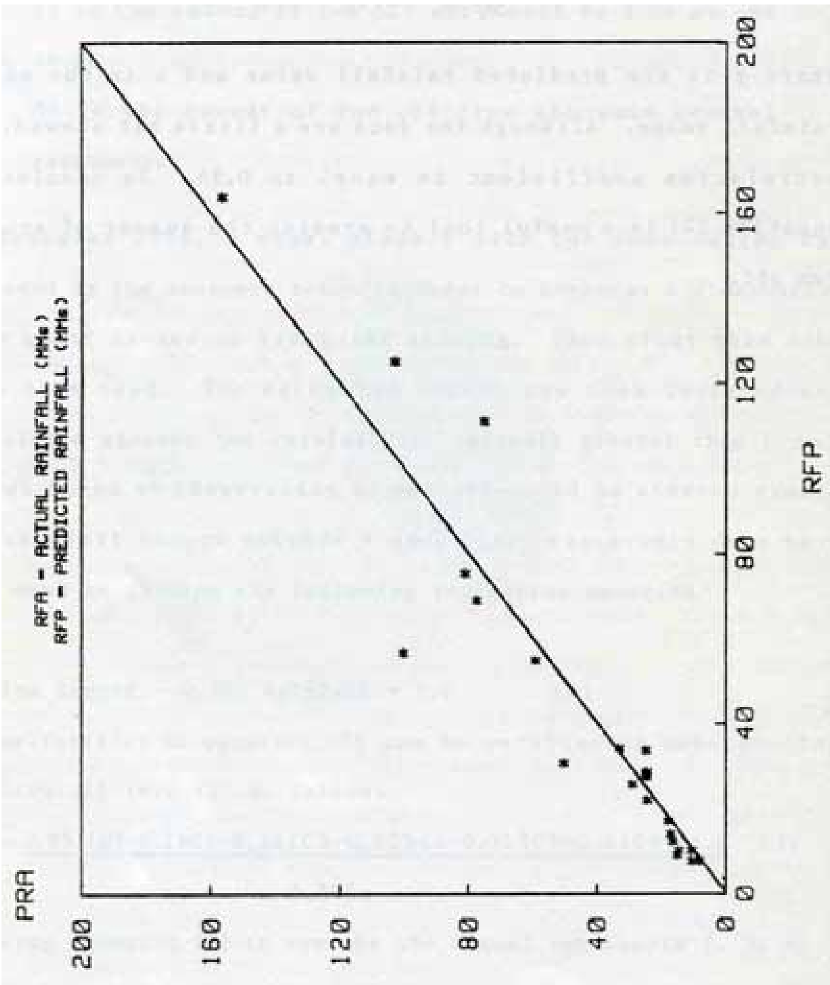

Fig 29 – Parwan Rainfall Prediction

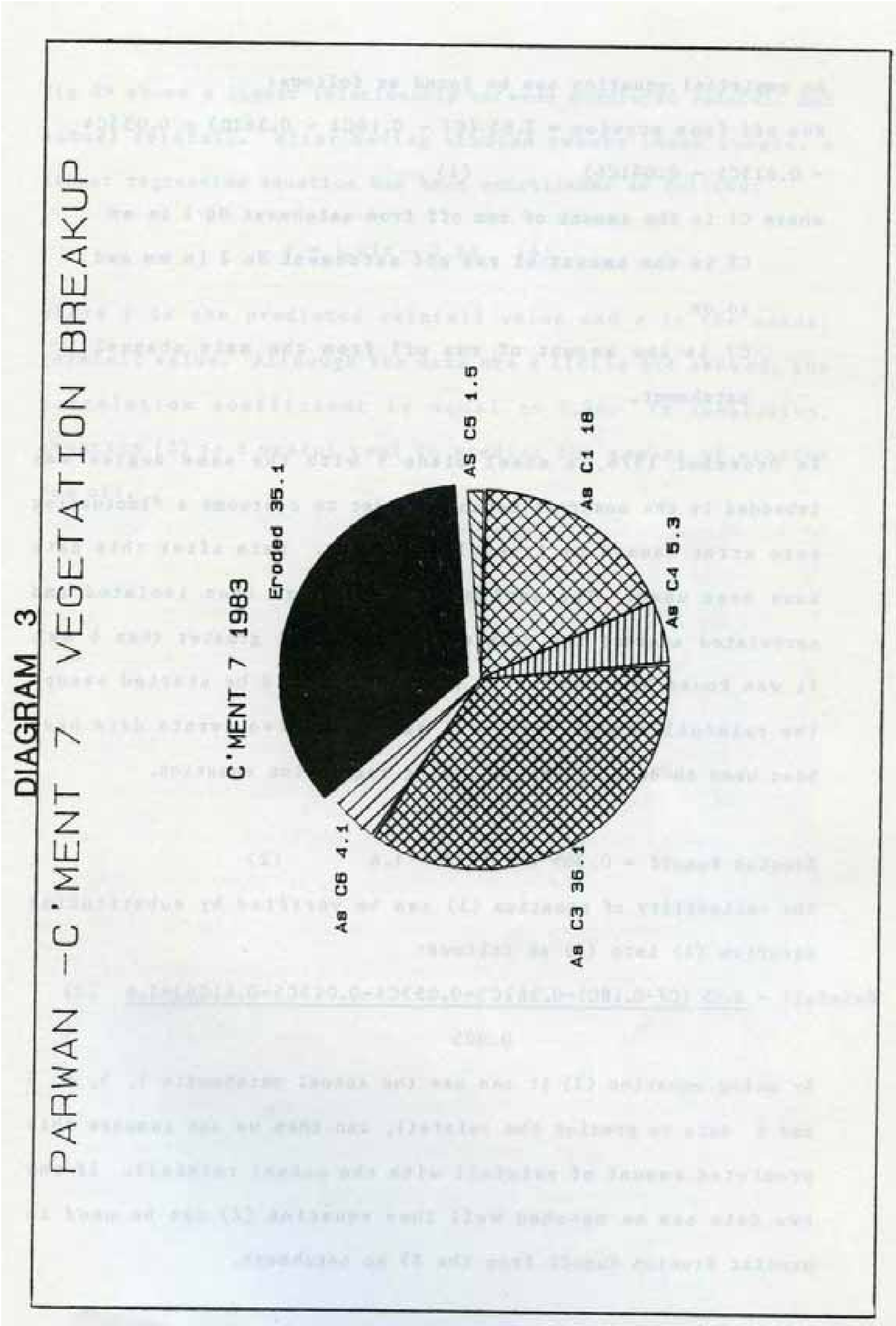

Diagram 3 – Parwan Catchment 7 – Vegetation Breakup

10 Conclusion and Further Studies

Run-off from catchments with a northerly aspect is always greater than from comparable catchments with southerly aspect; soil moisture content on the northerly aspects is always less than on the southerly aspects. Hence, the vegetation growth on the southerly aspects is always denser and better than on the northerly aspects. The denser vegetation provides increased resistance to water and soil movement. The net results are reduced surface run-off and reduced soil erosion.

Continued monitoring and analysis is required to assess fully the effects of the various treatments applied. However, some preliminary conclusions can be drawn to assist in the development of improved pasture management systems for areas such as this.

Specifically, the establishment of deep rooted perennial pasture produces significant reductions in run-off and associated soil loss. This is observed even on the drier northern aspects. Provided the timing of grazing and the number of stock involved are both carefully regulated, good pasture can be maintained even under difficult conditions, thus significantly reducing onsite soil degradation and deleterious offsite effects.

The work carried out in the catchment over the past 30 years clearly illustrates the importance of soil conserving management techniques, both for landholders and for the community at large.

It is essential that the use of such techniques maintained by extended in this highly unstable catchment area.

Further Studies: The next phase of this study is to investigate these physical relationships, and attempt to predict them – in particular to use the research results for ungauged catchments. Preliminary examinations have been made on a number of existing hydrological models mainly developed from USA hydrological data. Unfortunately none of these seem to meet Victorian conditions adequately. Thus it is necessary to collect more local data and to use these in developing models to suit the location.

In addition, the Experimental Area serves as part of a secondary school education programme on the subject of soil erosion. Numerous secondary schools have arranged to visit the area as part of their school curriculum. It is expected that this activity will continue for the next ten years.