Pertanika 9(3), 277 – 284 (1986)

Soil Temperature Regimes under Mixed Dipterocarp Forests of Peninsular Malaysia

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Key words: Soil temperature regimes; mixed dipterocarp; forested; open; various depth; Peninsular Malaysia.

ABSTRAK

Regim suhu tanah-tanih di kawasan berhutan dan lapang pada kedalaman 5, 10, 20 dan 30 cm telah dilapur berasaskan pada data-data selama dua tahun. Keputusan menunjukkan suhu tanah-tanih kawasan berhutan sentiasa lebih rendah daripada kawasan lapang sebanyak 4 – 6°C disebabkan 'kesan naungan' tumbuhan hutan. Paras kedalaman 5 cm di kawasan lapang menunjukkan variasi terbesar, sementara tiada berbezaan bererti dapat dikesan antara paras-paras yang lain di kawasan berhutan. Purata berpemberat untuk suhu profil tanah-tanih bagi kedua-dua keadaan adalah mengikut purata suhu udara. Bagaimanapun, suhu kawasan lapang sentiasa mencatatkan nilai yang lebih rendah.

ABSTRACT

Soil temperature regimes of forested and open conditions at selected depths of 5, 10, 20 and 30 cm, were reported based on data collected over a two-year period. Results showed that temperature of soil under forest cover was consistently lower than of the open by 4 to 6°C due to 'shading effect' of forest cover. The top 5 cm layer in the open showed the greatest variation whilst insignificant differences were observed among layers under forest. Weighted average soil profile temperature for both conditions seemed to follow closely the mean air temperature. However, open air temperatures consistently recorded lower values.

INTRODUCTION

Soil temperature plays an important role in plant growth by affecting biochemical and physical activities taking place in the soil. Among others, it influences germination, decomposition of organic residues and rate of absorption. Fluctuation in soil temperature to a certain extent, also affects movement of water both in the vapour and liquid phases through soil (Adjepong and Afriyi, 1979). Temperature in soil layers varies temporally and spatially in response to changes in radient, thermal and latent energy exchanges which take place primarily at the soil surface. Temporal fluctuations follow a diurnal cycle during which time the soil can be considered as an 'energy sink' during the day and 'energy source' during the night.

In the tropics, a number of studies on soil thermal regime have been conducted pertaining mainly to agricultural areas (Lal and Greenland, 1979). However, very limited work has been carried out on a forest environment. Continuous monitoring of this variable in a remote forest area is rather difficult, yet the long term record of sufficient detail will be of great importance to scientists. This paper examined the soil thermal regimes under a forest environment and open condition for a two-year period and subsequently analyzed the spatial and temporal differences between them.

SOIL DESCRIPTION AND METHODOLOGY

Study plots for soil temperature monitoring were located in Jengka Forest Experimental Basin, Pahang in conjunction with the Forest Hydrology Research Project *(Fig. 1)*. Geologically, the basin in underlain by Upper to Middle Triassic Sedimentary rocks with parent materials predominantly made up of shales and sandstones. The major soil series found in the area are Bungor, Durian and Jempol soil series. However, the two study plots are located on two minor series namely Kedah (Typic Paleudult family) and Kemuning Soil Series (Orthoxic Tropudult) respectively. The former series is generally confined to ridgetop and hill slopes with a sandy loam texture; the profile development is juvenile and shallow. The latter series occur more on undulating areas with sandy clay loam topsoils to fine clay subsoils.

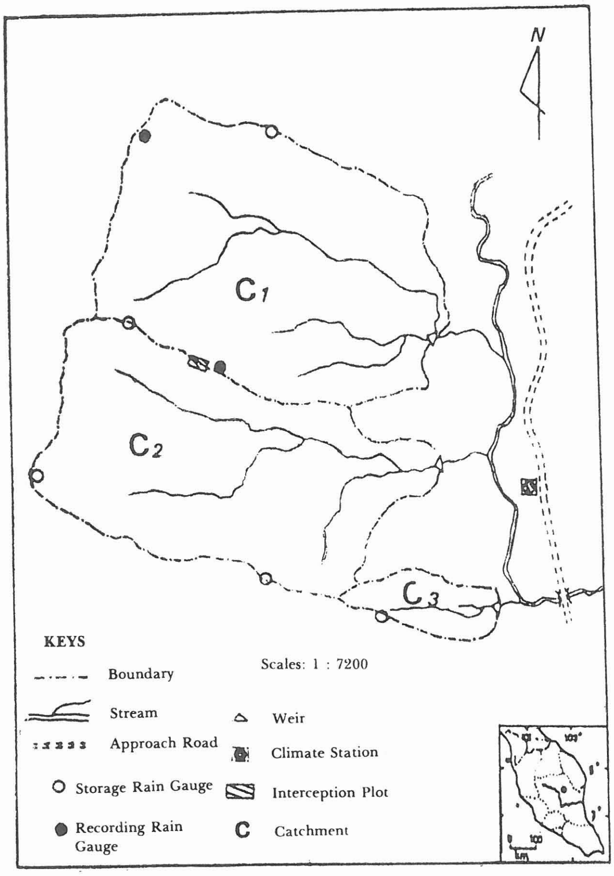

Fig. 1: Instrumentation in the Jengka Forest Experimental Basin.

Topographically, the area is one of medium convex hills characterised by slope segments rising quite abruptly from narrow valley floors. The steepest slope is about 50 – 60% and the relief ranges from 80 – 325 m a.s.l. with a south-easterly aspect. The vegetation consists of a virgin mixed-dipterocarp forest dominated by Keruing-Meranti species. The dominant species are *Shorea leprosula, Shorea bracteolata, Dipterocarpus cornutus* and *Eugenia* spp.

Climatic descriptions of the sites using mean values based on a four-year period (1979/80 – 1982/83) are as follows:

Annual rainfall	:	2479 mm
No. of raindays	:	168
Air temperature		
Mean Max.	:	32.8°C
Mean Min.	:	2.1°C
Relative Humidity	:	82.3%
Windrun	:	21.2 km/day
Evaporations (US 'A' type)	:	3.2 mm/day
Sunshine	:	4.9 hrs/day

The rainfall pattern of this area is typified by two peaks which coincide with the North-east monsoon (October – December) and the transitional period (March – May) (Abdul Rahim, 1983). The highest rainfall occurs in November and April while the lowest either in January or February. The bulk of the rain falls mostly during the afternoon or late evening, a character of the convectional type of rain. The mean temperature is 26.5°C and shows little variation throughout the year. The daily maximum and minimum air temperatures are moderate. The mean daily maximum is highest in July (34.4°C) while mean daily minimum is lowest in January (18.9°C). The absolute maximum temperature measured is 36.0°C and the absolute minimum 16.0°C.

The two study plots are located on different sites; one is in the open which is located at the climate station and the other is under forest in the interception plot at about 165 m a.s.l. *(Fig.*

1). At both sites, right-angled earth thermometers were inserted for various depths at 5, 10, 20 and 30 cm with an expected accuracy of +/−0.1°C. A thermometer at 100 cm depth was only installed towards the end of the study period. Soil temperature was read directly from the thermometer three times a day at 0800, 1200 and 1800 hrs respectively. All temperature measurements were completed within one hour and the order of sampling was fixed beginning with the open site first. Monthly soil temperature was computed from the mean daily temperature which was based on three daily readings over the month. Subsequently, a weighted soil profile temperature was obtained by averaging the monthly temperature of four depths and weighted against their corresponding depth-intervals as the interval between each depth was not uniform.

RESULTS

The monthly mean soil temperatures for both sites are given in Tables 1a and 1b. Lower soil temperatures were observed in December and January for all depths under open and forest respectively. The lowest temperature under forest ranged from 22.8°C at 5 cm depth to 23.5°C at depth 30 cm; the corresponding temperatures in the open varied from 27.1°C at 30 cm to 28.5°C for the same depth. On the other

TABLE 1a

Monthly and profile average soil temperature at selected depths in the open (1981 – 1982)

	Open (climate station)									
	1981					1982				
	Depth (cm)					Depth (cm)				
Month	5	10	20	30	Profile* Avg.	5	10	20	30	Profile Avg.
Jan	28.8	28.4	28.0	28.0	28.2	29.7	28.7	27.7	27.4	28.1
Feb	30.2	29.9	29.6	29.3	29.7	31.9	30.6	29.4	28.9	29.9
Mar	31.3	30.8	29.9	29.5	30.2	32.4	30.9	29.5	29.3	30.2
Apr	30.4	30.1	29.4	29.1	29.6	30.8	30.4	28.9	29.1	29.5
May	30.8	30.7	29.9	29.5	30.1	31.3	30.8	30.0	30.1	30.4
Jun	33.8	30.9	30.1	29.6	30.7	31.3	30.7	29.8	29.5	30.1
Jul	30.6	30.3	29.7	29.3	29.8	30.5	30.1	29.1	28.8	29.3
Aug	32.0	31.4	30.1	29.5	30.4	30.5	30.2	29.7	28.9	29.7
Sep	30.9	29.8	29.6	29.1	29.7	30.8	30.4	29.8	28.9	29.8
Oct	29.4	30.3	29.9	29.1	29.6	30.2	29.6	28.7	28.5	29.0
Nov	29.9	29.2	28.6	28.4	28.9	30.3	29.5	28.7	28.4	29.0
Dec	28.5	28.0	27.2	27.1	27.5	28.5	28.0	27.3	27.1	27.6
Mean annual	30.6	30.0	29.3	29.0	—	30.7	30.0	29.1	28.7	
Std. dev.	1.43	1.02	0.92	0.75	—	1.02	0.89	0.85	0.83	—
Coef. var.	4.68	3.38	3.13	2.61	—	3.32	2.98	2.92	2.89	—

*Weighted average

TABLE 1b
Monthly and profile average soil temperature at selected under depths under forest (1981 – 1982)

	Forest (interception plot)									
	1981					1982				
	Depth (cm)					Depth (cm)				
Month	5	10	20	30	Profile* Avg.	5	10	20	30	Profile Avg.
Jan	22.8	23.1	23.5	23.7	23.4	23.0	23.2	23.4	23.6	23.4
Feb	23.7	23.8	24.0	24.6	24.1	24.0	24.1	24.2	24.3	24.1
Mar	24.1	24.1	24.3	24.5	24.3	24.5	24.4	24.6	24.8	24.6
Apr	24.6	24.6	24.7	25.1	24.8	24.5	24.4	24.5	24.7	24.5
May	24.9	24.9	24.9	25.1	25.0	24.0	24.7	23.9	25.0	24.4
Jun	25.0	25.0	25.0	25.3	25.1	24.7	24.9	25.0	25.3	25.0
Jul	24.4	24.4	24.4	24.3	24.4	24.3	24.4	24.4	24.6	24.4
Aug	24.6	24.5	24.7	24.9	24.7	24.1	24.2	24.3	24.4	24.3
Sep	24.6	24.5	24.7	24.8	24.7	24.3	24.4	24.4	24.6	24.4
Oct	24.8	24.7	24.7	24.9	24.8	24.3	24.2	24.2	24.4	24.3
Nov	24.1	24.0	24.2	24.4	24.2	24.5	24.3	24.2	24.4	24.4
Dec	23.6	23.6	23.5	23.5	23.5	23.8	23.8	24.0	24.0	24.1
Mean annual	24.3	24.3	24.4	24.6	—	24.2	24.3	24.3	24.5	—
Std. dev.	0.92	0.56	0.50	0.55	—	0.45	0.43	0.39	0.44	—
Coef. var.	3.77	2.32	2.07	2.25	—	1.86	1.78	1.63	1.79	—

*Weighted average

hand, the highest soil temperature did not show any fixed pattern over the study period. Accordingly, the highest mean temperature occurred at 5 cm (33.8°C) for the open area and at 30 cm (25.3°C) under forest in June. Generally, the soil temperatures under forest were consistently lower than that of the open by about 4 – 6°C *(Fig. 2)*. Comparable results were obtained from a study in Nigeria with values ranging from 2 – 4°C (Oguntoyinto and Oguntala, 1979). In a similar study conducted in a lowland dipterocarp forest at the Pasoh Research Centre, Negeri Sembilan, a slightly lower value at selected depths was recorded (Soepadmo and Kira, 1977) based on hourly monitoring for three consecutive days.

In that study, at depth between 10 – 15 cm, the soil temperature varied from 22.7°C to 25.3°C at 0900 hrs; at depth 25 cm, it ranged from 21.3°C to 24.8°C. The values, however, might not be representative on an annual basis due to its short duration of monitoring.

For the open area, significant differences in temperature were observed at various depths (t values ranged: 2.25 – 10.77 at 95%). As expected, the temperatures at the 5 cm depth showed high fluctuations *(Fig. 2)*. In contrast only small differences in temperature were evident at the various depths under forest. In addition, the fluctuation in temperature was relatively less variable compared to the forest area. It was observed that the soil temperature slightly decreased with depth in the open. However, this was not obvious under forest. Perhaps temperatues at greater depths e.g. 50 or 100 cm are required in order to accentuate the above conceivable trend.

Figures 3 and *4* show that the weighted average soil profile temperature for 5 to 30 cm depths seemed to follow closely the mean air temperature for both conditions, but less pronounced under forest. It was also obvious that air temperatures in the open (1.5 m above ground) was consistently lower than that of soil temperature throughout the year by approximately 2 – 3°C. A difference of up to 7°C has been reported between air temperature at 1.5 m and under grass at 10 cm depth (Hill, 1966).

DISCUSSION

Insolation is influenced by vegetation cover, climatic variables, slope-aspect, and thermal properties of the soil. Slope and aspect are more important in temperate countries that in the tropics where the sun declination is small. For example, Hill (1966) reported that only minor differences were observed when comparing forest sites having different slopes. Under normal conditions in the open, upper soil layers absorb the greatest part of shortwave radiation. As a result, temperature variation at the first 5 cm layer is high as indicated by the coefficient of variation (Table 1a and 1b).

There is a difference of about 100 m in elevation between the open plot and the forested plot; the latter plot being situated on a 30% slope. Hence, a slight difference in temperature

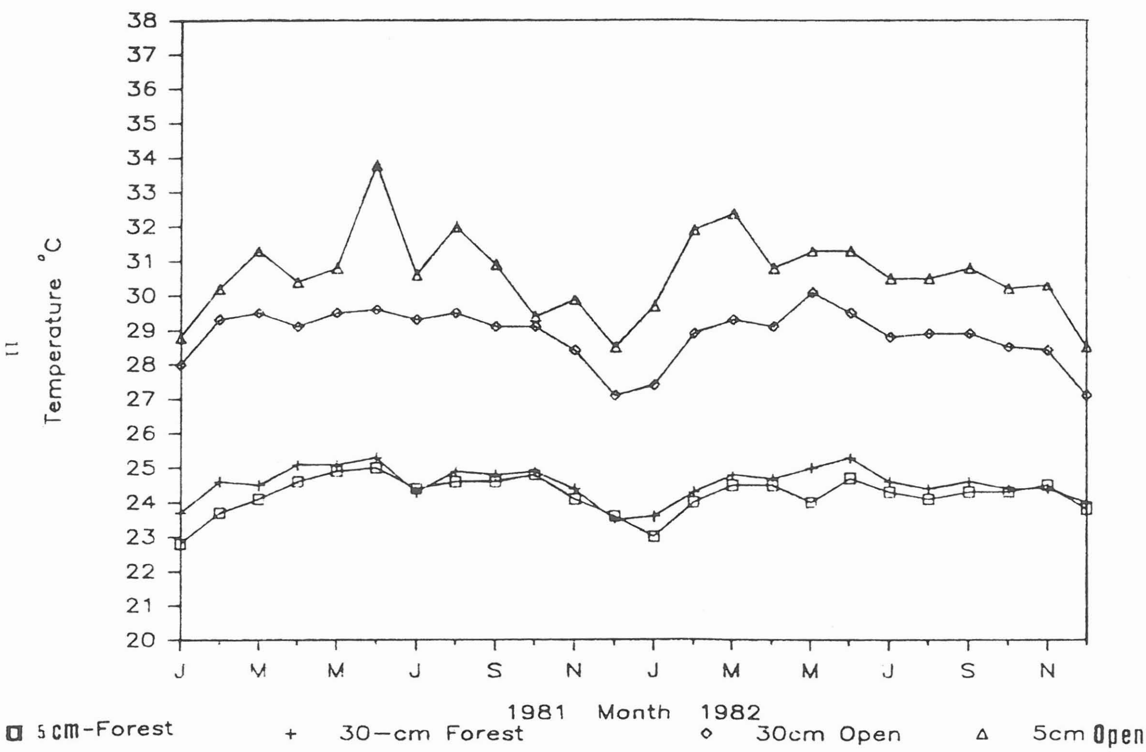

Fig. 2: Soil temperature at selected depths (5 and 30 cm) in open and under forest.

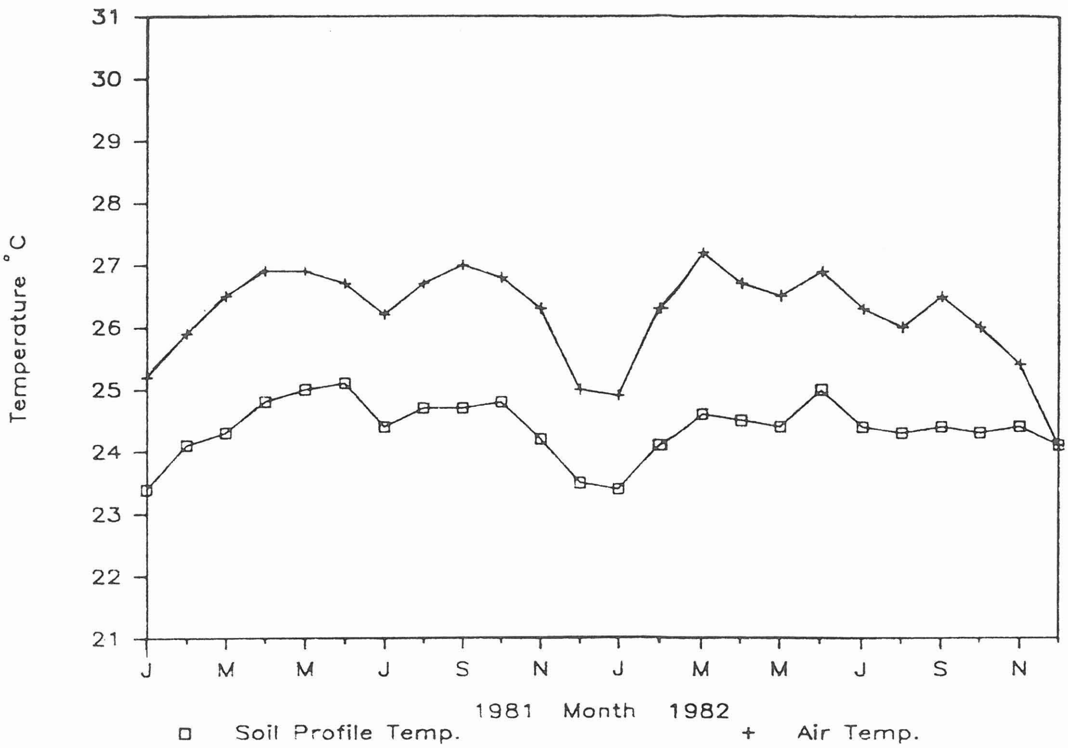

Fig. 3: Average soil profile temperature and air temperature at 1.5 m under forest

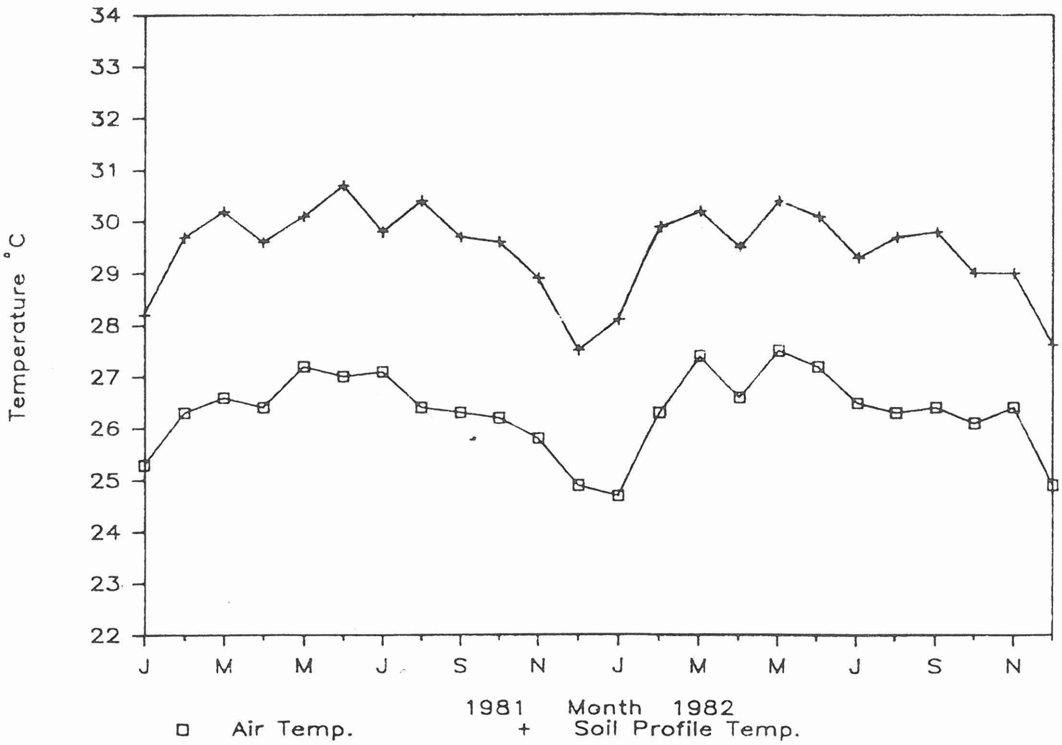

Fig. 4: Average soil profile temperature and air temperature at 1.5 m in open (climate station).

was expected between sites due to the lapse rate effect. However, such a difference, if there was any, would be small (approximately less than 1°C) and would not greatly account for the significant difference observed between them. Moreover, elevational effect on soil temperature is relatively complex and is compounded by site characteristics, vegetation and weather variables (Gary, 1968). Furthermore, in this case, the elevation effect was in part probably masked by the presence of a dense vegetation cover in the forested plot which modified microclimate near the ground.

A "shading effect" was the most likely cause for the lower soil temperature under forest by about 4 – 6°C compared to the open condition. Under forest condition, the upper canopy forms a surface where a considerable fraction of incoming radiation is absorbed (Van Wijk and de Vries, 1963). The remaining part is absorbed in the lower layers of the forest and ultimately at the soil surface. In addition, reflectivity effect of natural surfaces is more pronounced on relatively smooth surfaces (e.g. soil or still water) but this effect diminishes if the surface is porous as in a forest canopy; albedo for tropical forest is estimated to be 0.12 to 0.13 (Oguntoyinto and Oguntala, 1979). Hence, forest cover has the effect of modifying the thermal regime of soil and also helps in moderating the temperature amplitude at the soil surface.

Diurnal and annual cycles of soil temperature are often affected by episodic phenomena such as cloudiness, rainstorm and drought. During the rainy period of December or January, it is possible that the forest soil becomes nearly saturated, at the least at the surface layer, as elicited from storm hydrograph responses. This high volume of water reduces the temperature rise resulting from absorption of a unit of heat. Due to this phenomenon, the months of December and January recorded the minimum soil temperatures for both the open and forested conditions. At the same time high water content also tends to increase soil thermal conductivity thus enchancing downward conduction of heat rather than its retention at the surface layer.

CONCLUSION

Results obtained from the present study give an indication of the differences of soil temperature between the open and forested conditions. The presence of a forest cover is the most important modifying factor in soil temperature regime besides other determinants such as slope and elevation. It is clear that due to 'shading effect' of forest cover, the soil temperature amplitude is lowered and results in an overall decrease in temperature under forest. Therefore any form of forest cover manipulation (e.g. logging, land opening and clearing) has to take into consideration the extent of soil exposure, otherwise drastic changes in soil temperature becomes unavoidable. This is pertinent because the above activities invariably entails a tremendous amount of soil disturbance especially in the construction of logging tracks and roads, and a substantial amount of canopy opening as in selective loggings. In addition, further observation in different types of vegetation cover and under various soil types is recommended.

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(Received 20 August, 1985)