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Air and Soil Temperature Characteristics of Two Sizes Forest Gap in Tropical Forest

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Abstract: This study was conducted to characterize soil temperatures at three depths in two gap sizes and to relate soil temperatures with other microclimatic parameters. This study was conducted at Air Hitam Forest Reserve, Puchong, Selangor from September to December 1997. Two gap sizes were chosen; large (500 m^2) and small (180 m^2). Continuous measurement on soil and air temperature and solar radiation were made for seven days. Due to availability of only one data logger, measurements of both gaps could not be made simultaneously. Measurement of soil temperature at three depths were made at the center of the gap while measurement of soil temperatures along a transect were made at 5 cm depth. The result shows that mean soil temperatures at 1, 5 and 10cm in the large gap were 25.51, 25.5 and 25.45°C, respectively. The mean soil temperatures in the small gap at 1, 5 and 10 cm were 25.26, 25.50 and 25.33°C, respectively. The soil temperatures were higher in the gap and change progressively to the edge of the forest. Simple linear regression analyses of soil temperature at three different depths and air temperature were made using the large and small gap data. In both gaps, there were strong relationship between 1 cm soil temperature and air temperature with R^2 of 0.96 for large gap and 0.65 for small gap. A linear relationship was found with R^2=0.57 between soil temperature of 1 cm depth and solar radiation in the large gap. This study concludes that the air temperature is the best variable to predict the soil temperature.

Key word: Soil temperature, forest gap, forest microclimate

INTRODUCTION

Soil temperature is among the factors affecting the ecological processes within the forest ecosystem. It regulates many processes such as rate of plant's development and growth[1], survival, soil physical properties, carbon dioxide efflux from soil, microbial activities, nutrient uptake efficiency and occurrences of the diseases[2].

Soil temperature is influenced by meteorological factors such as solar radiation, air temperature, soil water content and also surface characteristics such as soil albedo, plant canopy[3] and ground litter. Topographical variables such as slope and aspect also influence soil temperature.

In tropical forest, the canopy filters the solar energy reaching the ground allowing small percentage of the energy absorbed by the soil. When forest gaps are formed, the protective canopy will disappear allowing much higher solar energy reaching the soil surface changing the soil temperature regimes of the newly formed gap[4]. This will further changes the soil microclimate which will encourage certain forest species to germinate thus creating regeneration of light demanding species. On the other hand, forest ecosystem processes such as forest succession may also affected soil temperature[5].

Gaps when formed developed their own microclimate. However, few studies have been conducted to relate gaps sizes and their microclimate parameters. This study was conducted to characterize soil temperatures at three depths in two gap sizes and to relate soil temperatures with other microclimatic parameters.

MATERIALS AND METHODS

The study was conducted at Air Hitam Forest Reserve, Puchong, Selangor. Air Hitam Forest Reserve has been gazetted to University Putra Malaysia in 1996 by Forest Department of Selangor. The Forest was gazetted for forest education and research purpose. It is about 1,248 ha and has six compartments.

The topography of the forest is rather undulating with 15 and 157 m above sea level. This forest has been classified as a rich Dipterocap forest of kempas kedondong. The forest has been logged before in 1930[6].

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Table 1: Instrument and parameter observed

Parameter measured	Instrument	Positioning
Soil temperature	1000-15 Soil temperature sensor	1, 5 and 10 cm depth
Air temperature	1000-16 Air temperature sensor	1 m
Solar radiation	LI-200SA Solar radiation sensor	2 m

After the logging operation, the Air Hitam forest reserve was classified as a secondary disturbed forest. The emergent canopy stand is about 20 m above the ground. The secondary layers are between 12 to 16 m above ground and the lower canopy consists of sapling and seedling.

Data were collected in two size of gap and shaded understorey. These two gap were located in the low area of compartment 12 Air Hitam Forest Reserve, Puchong, Selangor. The selection was due to factors such as easy access and both gaps were located near to each other. The gaps were considered as circular in shape. The size of the large gap and the small gap are approximately 500 and 180 m^2 with 26 and 14 m in diameter along North and South transect[7].

Parameters such as soil temperature, solar radiation and air temperatures were monitored during the study period. All the data were recorded in automatic datalogger Licor-1000. Measurements were recorded every 60 sec and average of 60 min interval of 24 h in a period of 7 day. The daily weather condition was recorded as clear, partly cloudy or cloudy. The parameter and instrument used are shown in Table 1. The instruments used were supported by battery power datalogger.

During the study, the data logger was placed 2 m height in the instrument enclosure to prevent from rainwater and solar radiation. The instrument enclosure was placed in the center of the gap. The solar radiation sensors were positioned on the platform of the instrument enclosure. Other sensors were also located at the same position.

Microclimate parameters such as solar radiation, light, soil temperature and air temperature were measured at both large and small gaps. However due to the limitation in instrument, the measurement at both gaps were made separately. Attempts were made if possible to time the measurement as close as possible between measurement so that the environmental conditions during the study were similar.

RESULTS AND DISCUSSION

Solar radiation: The mean solar radiation in large gap (500 m^2) from 26 to 30 September, 1997 was 220 and 149 W m^{-2} in the small gap (180 m^2) during 13 to 19 December, 1997, respectively (Table 2). The mean solar radiation in large gap was higher than the small gap by 71 W m^{-2}. This result was supported by Kamisin[7] study at the same gap with 139 to 289 W m^{-2} in the small gap and 153 to 411 W m^{-2} in large gap Ashton[4] recorded similar results in a forest gap in Sri Lanka.

Table 2: Summary of microclimate observation on the mean, maximum and minimum values on the small gap (180 m^2) and large gap (500 m^2)

		Solar radiation (W m^{-2})	Air Tempe-rature (°C)	Soil temperature (°C) 1 cm	5 cm	10 cm
Large gap						
26 to 30 September, 1997	Mean	220	25.76	25.51	25.5	25.45
	Max	571	32.34	29.46	26.5	25.92
	Min	2	22.30	24.10	24.84	25.02
Small gap						
13 to 19 December, 1997	Mean	149	24.85	25.26	25.5	25.33
	Max	469	29.93	27.41	26.5	25.86
	Min	1	21.99	23.82	24.7	24.81

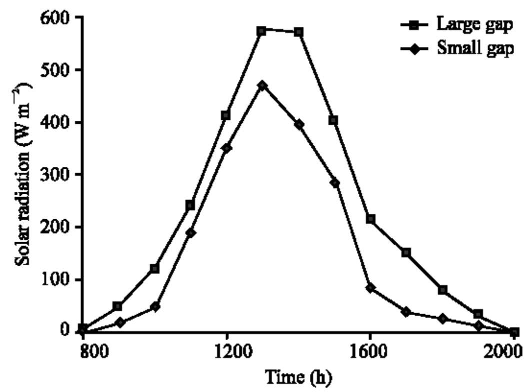

Fig. 1: Hourly variations of solar radiation in the large gap (500 m^2) and small gap (180 m^2) within the duration of the study. Small gap was measured during 13 to 19 December 1997 while large gap was measured during 26 to 30 September 1997

The value of solar radiation during this study is slightly lower than those found by in other study[7] in different month: mean of 224 W m^{-2} in small gap and 317 W m^{-2} in large gap. The hourly variation of solar radiation for both gaps within the time study is shown in Table 2 and Fig. 1. The maximum value peak for both gaps occurred at the same time (1400 h). Maximum value of solar radiation in large gap and small gap were 571 and 469 W m^{-2}, respectively. The data also shows that solar radiation value exceeded 200 W m^{-2} was recorded longer in large gap with 6 h during 26 to 30 September. 1997 as opposed to 4 h in small gap during 13 to 19 December, 1997. The wider the gap, the more it is exposed to solar radiation[8,9].

The maximum value of solar radiation in large gap during cloudless day (15 December, 1997) and cloudy day (16 December, 1997) were 552 and 463 W m^{-2}, respectively (Fig. 2). In the small gap the maximum value in cloudless day (15 December, 1997) and cloudy day

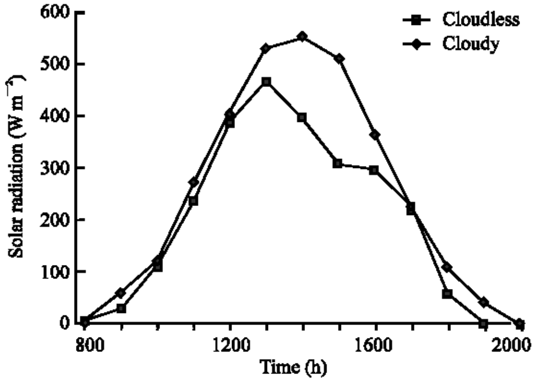

Fig. 2 : Diurnal pattern of solar radiation in the large gap (500 m^2) during cloudless day (21 September 1997) and cloudy day (28 September 1997)

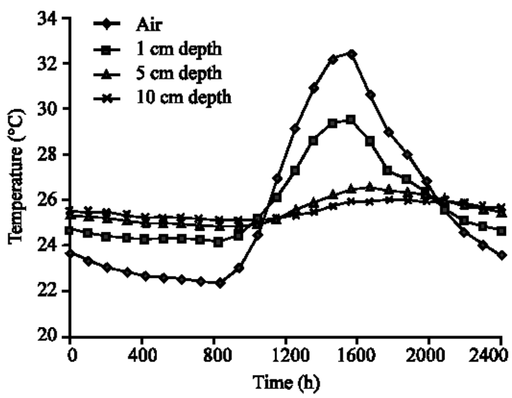

Fig. 3: Mean hourly air temperature and soil temperature at 1, 5 and 10 cm depth in the large gap (500 m^2) from 26 to 30 September,1997

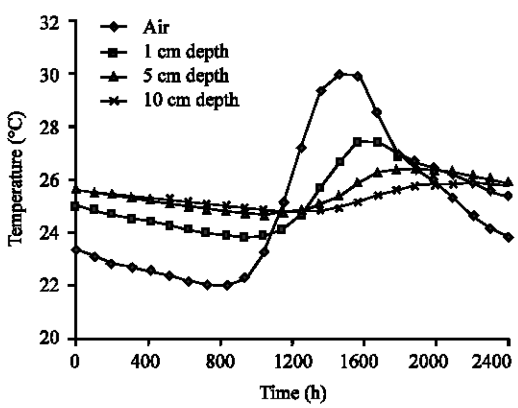

Fig. 4: Mean hourly air temperature at 1m height and soil temperature at 1 cm, 5 cm and 10 cm depth in the small gap (180 m^2) from 13 to 19 December, 1997

(16 December, 1997) were 775 and 161 W m^{-2}, respectively. It has been proven that the cloud intercepts the solar radiation that reaches the earth.

Soil temperature: Mean soil temperature at 1, 5 and 10 cm depth in large gap (26 to 30 September, 1997) were 25.51, 25.4 and 25.45°C, respectively (Table 1). In the small gap (13 to 19 December, 1997) the mean soil temperature at 1, 5 and 10 cm were 25.26, 25.5 and 25.33°C, respectively (Fig. 3). The mean soil temperature in small gap was different from the large gap due to the shading effect by the forest plant. This was supported by another study[10], that mean monthly soil temperature at 1 cm depth was extremely variable between gap because it is strongly influenced by the degree of shading by the forest floor plant

One centimeter soil temperature come closed to the air temperature follows by the 5 and 10 cm depth during day and reversed in pattern during the night (Fig. 3). It was due to the incoming solar radiation received by the soil surface. The maximum value of mean hourly soil temperature in large gap at 1, 5 and 10 cm depth were 29.46, 26.5 and 25.92°C, respectively. The 1 cm soil temperature peak at the same time with the air temperature at 1400 h. There have been lag effects between the soil temperature at 1, 5 and 10 cm about 1 h during the maximum value (1500 h at 1 cm depth; 1600 h at 5 cm depth; 1700 h at 10 cm depth). The lag effect was caused by the heat propagated downward in a form of wave[11].

The maximum value of soil temperature in small gap at 1 cm depth was 27.41°C while at 5 cm depth was 26.5 and 25.86°C in the 10 cm depth (Fig. 4). The mean maximum soil temperature in small gap at 1 cm depth occurred 1 h early than the 5 cm depth (1600 h; 1 cm depth and 1700 h; 5 cm depth). The 10 cm depth lag about 3 h than the 5 cm depth (1700 h; at 5 cm depth and 2000 h; at 10 cm depth). The heat from the surface propagated downward by heat conduction in the form of wave[11]. The 1 cm soil temperature differences between the small gap and large gap was due to the degree of shading by forest plant.

The cooling in the large gap was twice as long as the period of heating. The loss of heat during the afternoon and night hours is more less the same as gain, the heat during the morning hour. During the heating period, the soil at 1 cm in the large gap increased it temperature about 0.8°C h^{-1} while the soil temperature at 5 and 10 cm increased by 0.2 and 0.1°C h^{-1}.

In the small gap the soil temperature at 1 cm increased at 0.5 in an hour. The soil temperature at 5 cm depth increased about 0.3 and 0.2°C h^{-1} in the 10 cm depth. In the night the temperature at 1, 5 and 10 cm decrease about 0.2-0.1°C h^{-1} in the small gap opposed to 0.3-0.1°C in the large gap.

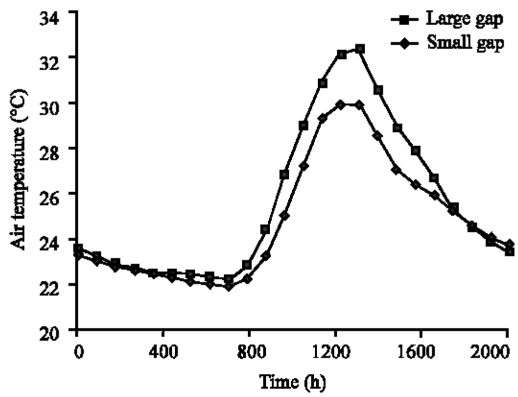

Fig. 5: Mean hourly air temperature in the large gap (500 m^2) and small gap (180 m^2). The observation were made on 26 to 30 September, 1997 in large gap and 13 to 19 December, 1997 in small gap

The air temperature affects the soil temperature. This can be seen by the similar curve of the soil temperature in large and small gap. The soil temperature is higher during the day and reduced steadily through the night because long wave radiation cooling takes place at the top and cool air comes downward. Therefore at night, air attained the lowest temperature followed in increasing order by 1, 5 and 10 cm soil depth. The diurnal range between this boundary does not appear to fluctuate by more than 1°C (Fig. 5).

A simple linear regression analysis shows a strong relationship between soil temperature in both gaps (Table 3). The R^2 in the large gap is higher than the soil temperature in the small gap because the normal distribution of air temperature in the large gap is wider than the small gap. The 1 cm depth soil temperature in large gap and small gap has stronger relationship than the 5 and 10 cm depth because heat transfers to the soil by conduction and has a lag effect.

The maximum soil temperature in the large gap along the NCS transects were 25.81, 28.62 and 25.35°C, respectively. In the small gap the maximum soil temperature along the NCS were 26.91, 27.07 and 25.37°C, respectively. Both gaps show high soil temperature in the center than the north and south due to the shading effect. This was because the soil temperature changes progressively away from the center of the gap due to the shading effect.

Diurnal soil temperature in the large gap shows the extreme data over long duration hour. The soil temperature in the center of the gap shows the highest value.

The magnitude of soil temperature differs with gap size, larger gap shows higher values of soil temperature compared to small gap. Soil temperature is highest at the surface, gradually decreasing with depth. The soil temperature data can be predicted using the solar radiation only in the large gap. The best way to predict the soil temperature data is using the air temperature data.

Table 3: Relationship of soil temperature and air temperature using regression analysis

Gaps	Soil depth (cm)	R^2	S.E	Equation
Large Gap	1	0.96	0.36	Soil temp. = 12.56 + 0.51 Air temp.
	5	0.63	0.38	Soil temp. = 21.98 + 0.14 Air temp.
	10	0.03	0.32	Soil temp. = 23.95 + 0.06 Air temp.
Small Gap	1	0.65	0.73	Soil temp. = 16.14 + 0.37 Air temp.
	5	0.15	0.59	Soil temp. = 23.21 + 0.09 Air temp.

Table 4: Relationship of soil temperature and solar radiation in large gap

Gaps	Soil depth (cm)	R^2	S.E	Equation
Large Gap	1	0.57	1.27	Soil temp. = 25.23 + 0.0007 solar
	5	0.07	0.67	Soil temp. = 25.57 + 0.009 solar

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