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A comparative study of soil heat flux in bare plot and jowar field at Pune

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ABSTRACT. Soil heat flux measurements were made in black cotton soil in a bare plot and a jowar fied, at Pune, using Thornthwaite heat flow discs. The reversal of sign of heat flux is delayed in the morning by about 45 min. and is advanced by about 30 min. in the late afternoon in the crop field. The net daily heat flux is generally negative in crop field and positive in bare plot.

The share of soil heat flux in day time energy budget with full crop cover was found to be 4 to 5 per cent of net radiation.

1. Introduction

Soil heat flux is one of the components of the energy budget used to estimate evapotranspiration. Being small, relative to sensible and latent heat fluxes, it is usually neglected in the budget over long enough periods such as a year. Over shorter intervals of a day or a month it may not be justifiable to neglect it without a proper examination of the variation of soil heat flux with season, soil characteristics, plant cover and soil moisture content.

Soil heat flux is either measured directly by using transducers or is estimated from soil temperature profile measurements. Padmanabhamurthy and Subramanyam (1961) studied the diurnal and seasonal variations of heat flow in sandy loam soil at Waltair using both the methods. Subramanyam and Ratnam (1970) estimated the soil heat flux in a sugarcane field (black clay loam soil) and open field (brown sandy loam soil) at Anakapalle from soil temperature measurements. Similiar estimates in the bare red laterite soil were made by Ramakrishna Rao *et al.* (1977) at Bangalore. Measurements using heat flux plates in bare plot (black cotton soil) at Pune were made by Kelkar *et al.* (1980).

Computation of soil heat flux from soil temperature distribution does not appear to be quite satisfactory because the method involves many assumptions regarding the soil constants. As the soil heat flux is small in magnitude, its accurate determination by direct measurements is preferable.

2. Materials and methods

An experiment was carried out in a bare plot of Central Agrometeorological Observatory, Pune (Lat. 18 deg. 32′N, Long. 73 deg. 51′E) and in a nearby jowar field to study the behaviour of soil heat fluxes. It is black cotton soil at both the locations. The crop (variety CSH-4) was sown on 10 July 1974 and harvested on 30 November 1974. The distance between the plants was 15 cm and that between the rows, 45 cm.

A Thornthwaite soil heat flow disc (diameter 25 mm; thickness 2.6 mm) was embedded horizontally in the soil at a depth of 5 cm at each of the two locations. The disc in the crop field was placed between two plants, on the slope of a ridge in the middle of the field. The output of the disc in the bare plot was 6.54 mv/cal/cm^2/minute and that of the disc in the crop field, 7.57 mv/cal/cm^2/minute. Spot readings of the output of both the discs were measured at 15 min. intervals (7.5, 22.5, 37.5 and 52.5 min.) every hour (LAT) using a Cambridge potentiometer round the clock. These were summed up and the hourly heat fluxes were calculated using appropriate conversion factors.

Observations were taken between 20 August 1974 and 14 September 1974 when the crop was

TABLE 1

Times (LAT) of reversal of flux and duration of positive flux

Date (1974)	Bare Plot		Crop field		Duration of +ve flux		Duration of sunshine hour
	—ve to +ve	+ve to —ve	—ve to +ve	+ve to —ve	Bare *h m*	Crop *h m*	
21 Aug	0752	1652	0807	1552	9 00	7 45	3.1
22 Aug	0737	1737	0807	1632	10 00	8 30	8.0
23 Aug	—	1707	—	1652	—	—	4.8
24 Aug	—	1722	—	1637	—	—	4.7
25 Aug	0737	1707	0752	1707	9 30	9 15	9.4
26 Aug	0707	1737	0752	1652	10 30	8 55	10.0
27 Aug	0707	1752	0837	1707	10 45	8 30	7.8
28 Aug	0722	1637	0837	1507	9 15	7 30	4.5
29 Aug	0707	1522	0807	1522	8 15	7 15	2.0
30 Aug	0752	1522	0807	1522	7 30	7 15	0.3
1 Sep	—	1637	—	1637	—	—	7.4
2 Sep	0722	1707	0807	1637	9 45	8 30	10.0
3 Sep	0737	1652	0800	1637	9 15	8 30	10.2
4 Sep	0722	1637	0807	1652	9 15	8 45	8.8
5 Sep	0722	1752	0822	1722	10 30	9 00	9.8
6 Sep	0722	1807	0807	1722	10 45	9 15	10.2
7 Sep	0707	1807	0752	1722	11 00	9 30	10.6
8 Sep	0707	1807	0752	1737	11 00	9 45	9.4
9 Sep	0707	1807	0807	1737	11 00	9 30	9.7
10 Sep	0737	1652	0837	1637	9 15	8 00	3.5
11 Sep	0722	1737	0807	1637	10 15	8 30	6.9
Average time	0724	1711	0809	1640	9 49	8 34	—
Range (min.)	45	165	60	135	—	—	—

TABLE 2

Times of occurrence of maximum positive flux

Time LAT (hr)	Bare plot	Crop field
1000-1100	2	2
1100-1200	10	3
1200-1300	13	8
1300-1400	2	12
1400-1500	1	4

in its active vegetative phase. In additions, observations were taken on four days after harvest when the stubble was still in the field.

Times of reversal of soil heat flux

The soil heat flux is considered positive when it is directed towards soil and negative in the opposite direction. The times of the reversal of flux are presented in Table 1. Soil heat flux changes from negative to positive around 0724 hr and from positive to negative around 1711 hr in the bare plot. In the crop field, these reversals take place around 0809 hr, and 1640 hr respectively. The reversal is delayed in the morning, on an average, by about 45 min. and is advanced by about 30 minutes in the late afternoon, in the crop field compared to bare plot. The times of occurrence of reversal in the morning both in the bare plot and crop field show relatively smaller day to day fluctuations in the morning than in the afternoon.

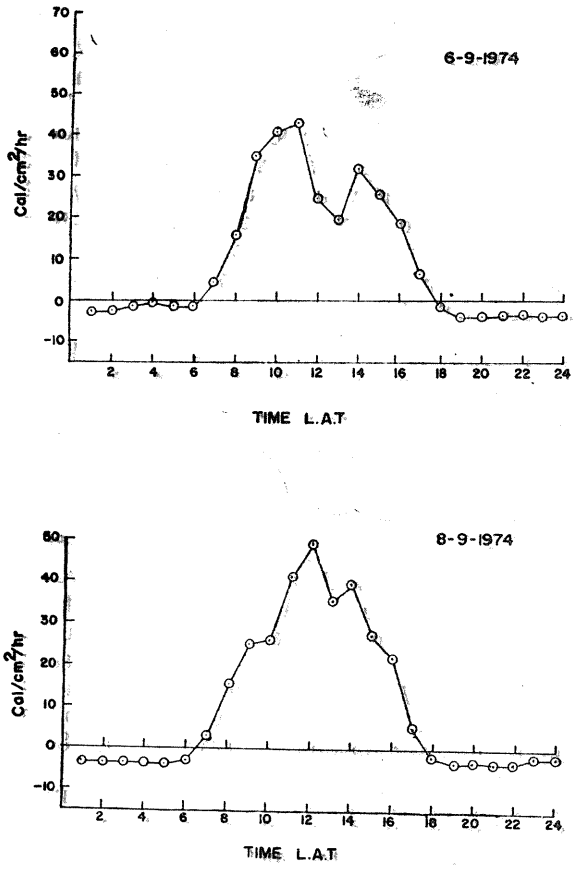

Fig. 1. Diurnal variation of net radiation over jowar crop at Pune

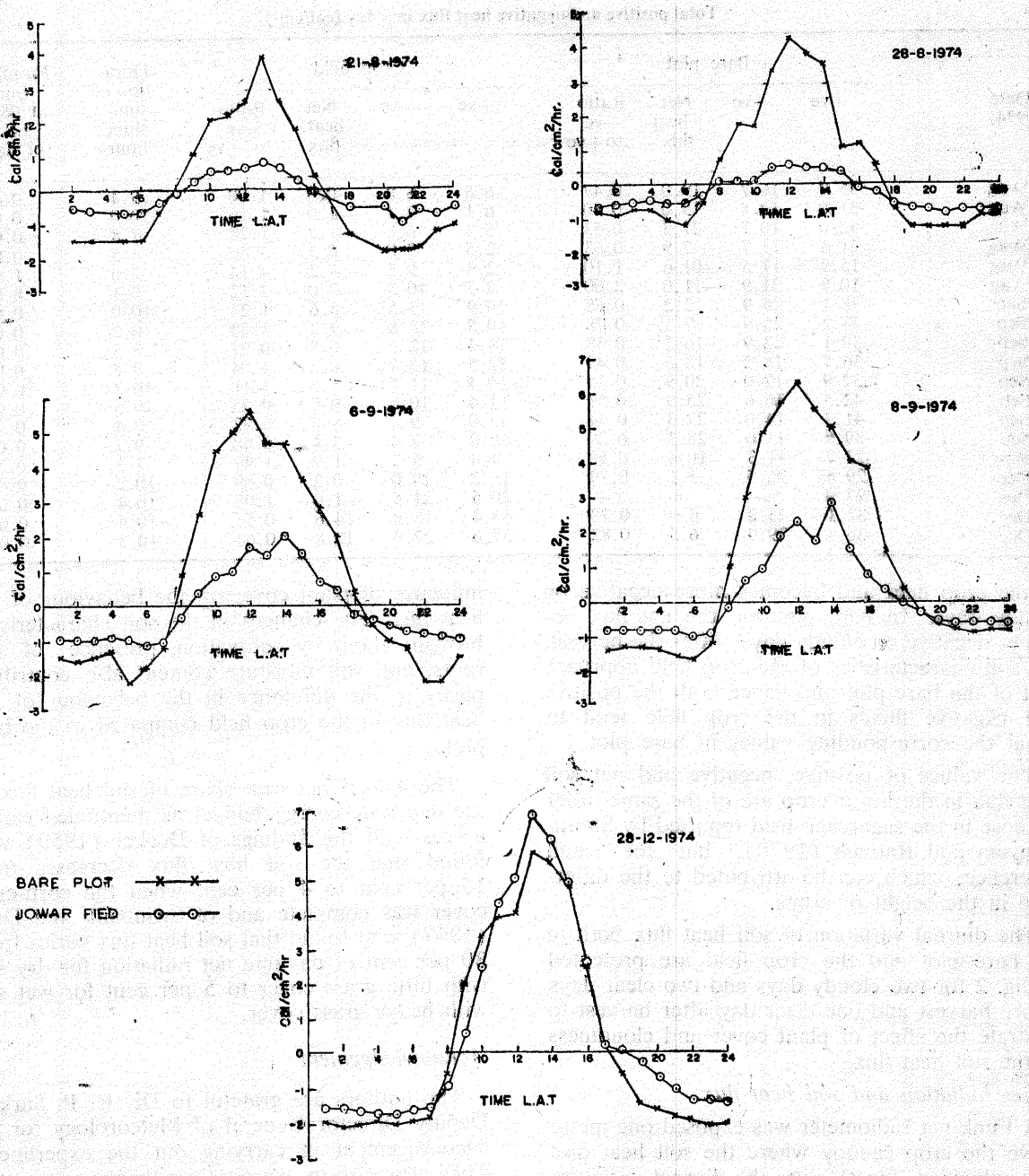

Fig. 2. Diurnal variation of soil heat flux in bare plot and in jowar field at Pune

Time of occurrence of maximum positive flux and its duration

It is also seen from Table 1 that the duration of the positive flux is shorter in crop field than in the bare plot, on an average, by about 75 min. The duration of positive flux is reduced in both the sites on cloudy days. It is seen from Table 2 that the maximum of positive flux occurred on about 80 per cent of the occasions between 1100 and 1300 hr in bare plot whereas in the crop field on 70 per cent of the occasions, it occurred between 1200 and 1400 hours.

Relative magnitudes of soil heat flux

Table 3 gives the magnitudes of the positive, negative and the net heat flux in the bare plot and the crop field. Both the positive and negative fluxes are smaller in the crop field compared to that in the bare plot. In the bare plot, the net heat flux is generally positive and fairly large. It is generally negative and small in magnitude

TABLE 3

Total positive and negative heat flux in a day (cal/cm²)

Date (1974)	Bare plot				Crop field				Duration of sunshine hours	Rainfall (mm) at 0830 I.S.T. of date
	+ve	—ve	Net heat flux	Ratio —ve to +ve	+ve	—ve	Net heat flux	Ratio —ve to +ve		
25 Aug	35.7	16.7	19.0	0.47	6.8	6.8	0.0	1.00	9.4	0.4
26 Aug	31.8	12.8	19.0	0.40	6.1	7.1	—1.0	1.16	10.0	0.0
27 Aug	32.0	10.7	21.3	0.33	5.3	6.8	—1.5	1.28	7.8	0.0
28 Aug	21.6	13.7	7.9	0.63	2.5	9.0	—6.5	3.60	4.5	0.0
29 Aug	15.9	17.5	—01.6	1.10	2.3	9.5	—7.2	4.13	2.0	1.9
30 Aug	10.9	21.9	—11.0	2.00	3.3	10.3	—7.0	3.12	0.3	8.8
2 Sep	38.1	25.9	12.2	0.68	10.9	13.5	—2.6	1.24	10.0	0.6
3 Sep	33.2	25.9	7.3	0.78	10.5	12.8	—2.3	1.22	10.2	0.0
4 Sep	39.1	22.9	16.2	0.58	13.4	12.7	0.7	0.95	8.8	0.0
5 Sep	36.7	18.2	18.5	0.49	12.5	13.0	—0.5	1.04	9.8	0.0
6 Sep	37.9	17.0	20.9	0.45	10.4	11.6	—1.2	1.11	10.2	0.0
7 Sep	42.5	16.6	25.9	0.39	11.4	10.8	0.6	0.95	10.6	0.0
8 Sep	41.3	14.0	27.3	0.34	13.0	9.4	3.6	0.72	9.4	0.0
9 Sep	39.9	11.6	28.3	0.29	10.8	7.4	3.4	0.68	9.7	0.0
10 Sep	21.7	11.3	10.4	0.52	4.8	6.7	—1.9	1.39	3.5	0.2
24 Dec	29.6	26.5	3.1	0.89	19.2	19.0	0.2	0.99	10.2	0.0
25 Dec	27.9	—	—	—	20.5	21.5	—1.0	1.05	10.4	0.0
28 Dec	32.1	25.2	6.9	0.78	33.4	18.8	14.6	0.56	10.4	0.0
29 Dec	36.4	29.9	6.5	0.82	35.6	22.8	12.8	0.64	10.3	0.0

in the crop field and becomes more negative on cloudy days. In bare plot too the net flux becomes negative on cloudy days. After the harvest, the soil characteristics of the crop field approach that of the bare plot and hence both the positive and negative fluxes in the crop field tend to equal the corresponding values in bare plot.

The values of positive, negative and net soil heat flux in the jowar crop are of the same order as those in the sugarcane field reported by Subramanyam and Ratnam (1970), but for small differences which can be attributed to the difference in the height of crops.

The diurnal variation of soil heat flux both in the bare plot and the crop field are presented in Fig. 2 for two cloudy days and two clear days before harvest and one clear day after harvest to illustrate the effect of plant cover and cloudiness on the soil heat flux.

Net radiation and soil heat flux

A Funk net radiometer was exposed one metre above the crop canopy where the soil heat disc was embedded. Fig. 1 gives the diurnal variation of net radiation over the jowar crop, on 6 September 1974 and 8 September 1974 which were mainly clear days with a few passing clouds around noontime. The magnitudes of positive net radiation on these days were 263.9 and 290.5 cal/cm² respectively, while the magnitudes of the positive soil heat flux were only 10.4 and 13.0 cal/cm². The share of soil heat flux in the day time energy budget was thus only 4 to 5 per cent of net radiation.

3. Discussion

The foregoing results of the comparative measurements of soil heat flux, reveal the significant influence of plant cover on the behaviour of soil heat flux. The changes in the soil characteristics brought about by cultivation, presence of the roots, and soil moisture content also contribute partly to the difference in the behaviour of soil heat flux in the crop field compared to the bare plot.

The 4 to 5 per cent share of soil heat flux in the day time energy budget as mentioned earlier agrees with the findings of Decker (1959) who found that the soil heat flux decreases from 15 per cent to 4 per cent when the corn-crop cover was complete and of Swinbank and Dyer (1967) who found that soil heat flux varies from 30 per cent of daytime net radiation for dry soil with little grass cover to 5 per cent for wet soil with heavy grass cover.

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