Journal of Agrometeorology 3(1 & 2) : 57-65 (June-December-2001)

Radiation and energy budget components over cropped surface and bare soil during LASPEX-97

A. M. SHEKH, M. KUMAR, V. PANDEY AND R. B. GAJJAR
Department of Agril. Meteorology, G.A.U, Anand-388 110

ABSTRACT

Radiation components, profiles of temperature and wind at two tower sites (10 and 30 m) of Anand recorded during intensive observational period (IOP) of May, July, September and December months during LASPEX-97 experiment have been used to study radiation and energy budget variations over cropped and bare soil surfaces. The diurnal variation of these components due to variation in surface characteristics such as bare soil, crops/vegetation type and its density have been studied. Results reveal that the net radiation varies with crop density. Reflectivity of short wave is reduced in cropped field. During May and December, sensible heat flux was more and during July and September less. Latent heat was more during monsoon phase. Partitioning of net radiation into other components is also given.

Key words : Radiation budget, Energy budget, Exchange coefficient, Reflectivity

The thermal environment status of crop canopies is determined by the net energy available for utilization in net exchange processes of latent, sensible, soil heat fluxes, heat stored in plant organs, and heat utilized for transpiration/respiration and metabolic activity. Climate near the ground layer strongly depends on the various components of energy and water balance in the system. The radiation properties, such as albedo and emissivity of the surface, determining net radiation are important in determining climate near the ground.

The radiation received by bare ground and the radiation budget over lush grass cover and through different crop species are different. The quantity of light penetrating to the ground as well as its diurnal variation depends on height, density and structure of the plant cover.

Wetting of the subsurface due to precipitation or irrigation reduces the short-wave reflectivity (albedo) and increases absorption of short-wave radiation by the surface. The latent heat flux (L) becomes an important component of the surface energy budget, while sensible heat flux to air (H) is considerably reduced. In the present paper, the effect of bare land and over cropped surface on radiation and energy fluxes in the different IOP months have been examined.

MATERIALS AND METHODS

For the present study, the slow response tower data and fast response Sonic anemometer data for the months of May, July, September and December 1997 at two sites (10 m and 30 m tower sites) of Anand were used. At 10 m tower Metek Sonic anemometer was installed during IOPs. Both sites have same type of soils whose physical characteristics are loamy sand type, with average bulk density of -1.5gcm^{-3}. During

Table.1 : Surface characteristics at two sites at Anand (Values in parenthesis indicate height of crops).

Tower Sites	May	July	September	December
10 m	Short grass (10cm)	Sun hemp (11cm)	Bare	Wheat (12cm)
30 m	Bare	Groundnut (12cm)	Groundnut (35cm)	Bare

different seasons, there was variation in the canopy cover as follows: (Table 1)

Energy budget

The energy balance equation can be written as

$$Rn = H + L + G + (P+M)$$

Where, H is sensible heat flux, L is latent heat flux. In the present study, the latent heat flux was calculated by energy balance equation (L = Rn-H-G). G is ground heat flux, P & M are energies stored or used in photosynthesis and metabolic activity. P & M can be neglected in comparison to H, L and G.

The sensible heat flux H was computed by eddy correlation method at 10 m tower site using fast response Metek sonic anemometer, whereas at 30 m site it was computed by profile method. The ground heat flux, G was measured by soil heat flux plate.

RESULTS AND DISCUSSION

Radiation budget

The diurnal variations of different components of radiation budget in the different seasons are depicted in Figs. 1(a-d) which were influenced by different crop surfaces.

During May at one site it was short grasses and at the second site it was bare soil surface. Incoming short wave radiation was practically same at both the sites and the peak reached at around 13 to 15 hrs of the day and it was of the order of 920 Wm^{-2}. The reflected short wave radiation did not vary much over grass and bare soil as during May the grasses were mostly dry. However the net long wave radiation was higher over grasses resulting in higher net radiation over grasses than on bare soil.

During July one site was covered with sunhemp (Table 1), a fibrous crop used for green mannuring, and the second site was covered with groundnut crop. There were slight fluctuations in incoming short wave radiation (Fig. 1-b) which may be due to cloudiness. The maximum incoming short wave radiation of 700 Wm^{-2} was received at 14-15 hrs. The reflected short wave radiation also did not vary much over the two crop surfaces. The diurnal variation of net long wave radiation showed large fluctuations over groundnut crop, which may be due to uneven coverage of the surface by crop where as

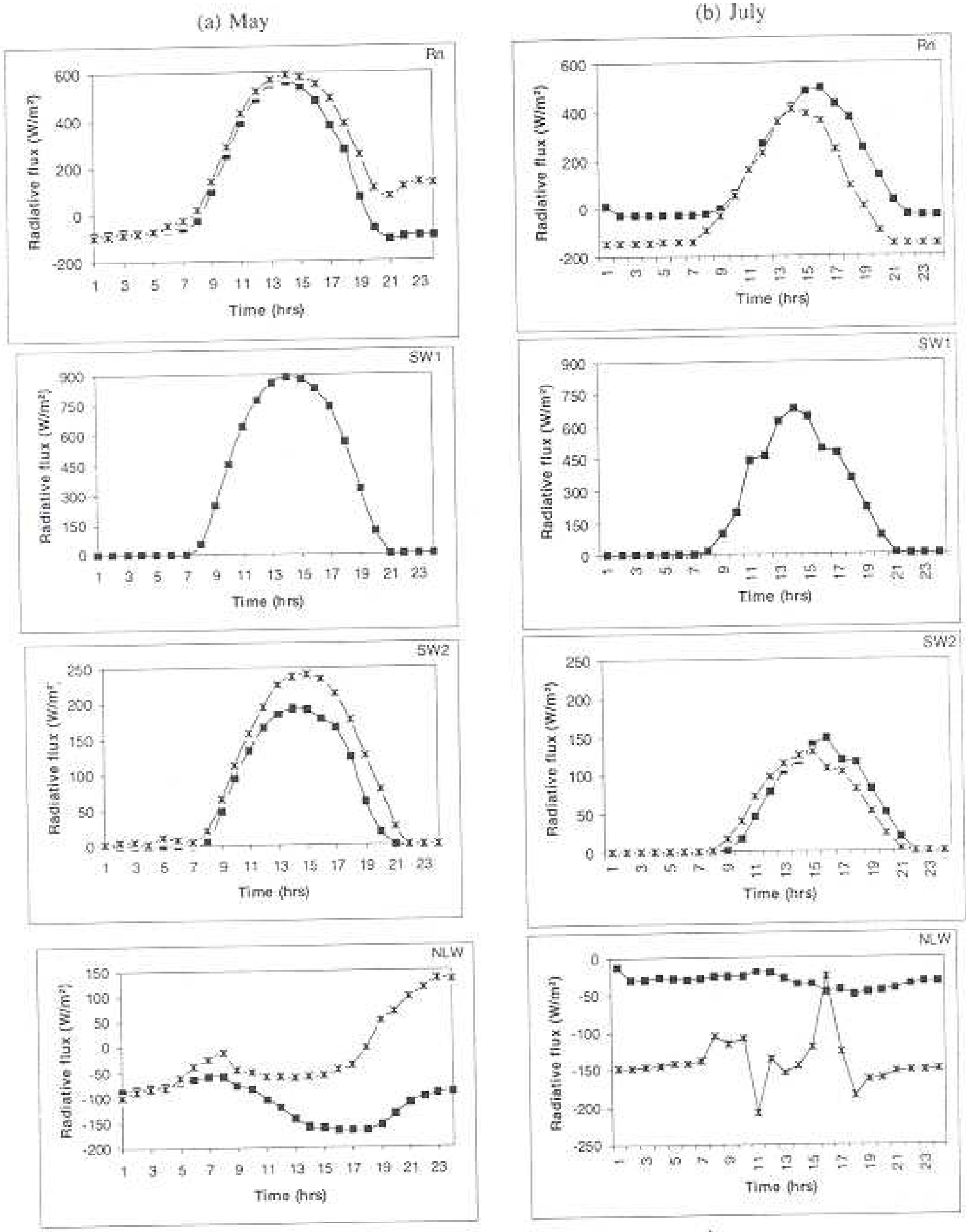

Fig. 1 (a-b) : Diurnal variation of radiation budget under crop (-■-) and bare (-x-) surface

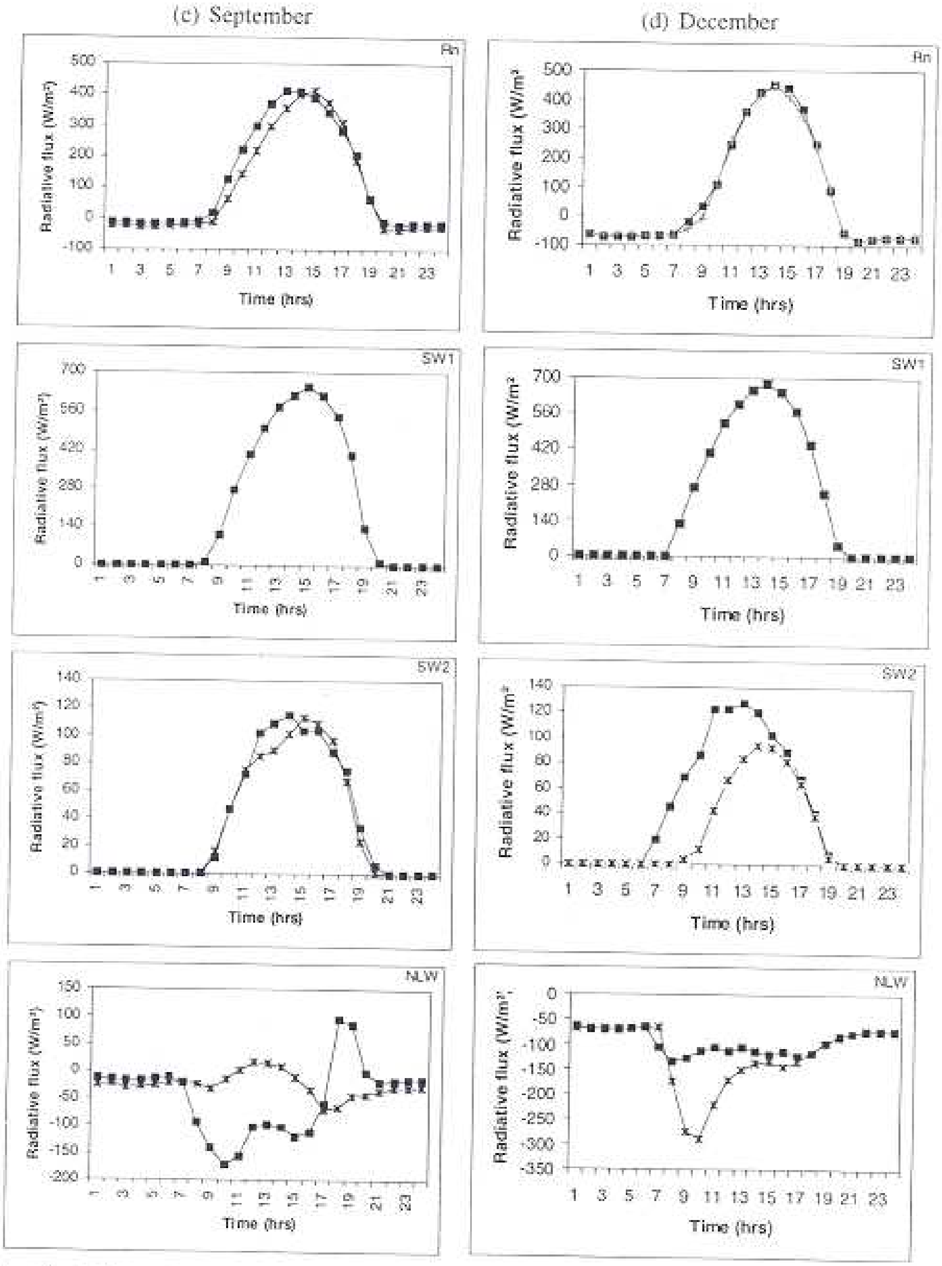

Fig. 1(c-d) : Diurnal variation of radiation budget under crop (-■-) and bare (-x-) surface

Table 2 : Average (24hrs average) radiation balance components in bare and cropped surface (in Wm^{-2}) during IOP

Radiation components	May		July		September		December	
	Bare	Grass	Sunn hemp	G'nut	Bare	G'nut	Bare	Wheat
Shortwave-incoming (SW1)	307	307	198	199	217	217	218	218
Shortwave reflected (SW2)	69	65	41	40	50	37	44	41
Net rad (Rn)	129	132	127	118	146	154	70	91
Net long wave (NLW)	-108	-110	-32	-40	-24	-26	-122	-86
Albedo (%)	22	21	21	20	23	17	20	19

the sunnhemp, which was very dense crop with uniform canopy, showed less fluctuation. This resulted in net gain in radiation i.e. net radiation was higher over sunhemp than groundnut. The significant differences in net radiation over two crops were observed during nighttime.

During September (Fig. 1-c) one site was kept bare as the sunhemp crop was embedded in soil for green mannuring and at other site groundnut crop was at pod development stage (height 30-32 cm). During nighttime no differences in reflected short wave radiation and net long wave radiation over two surfaces were observed. Over groundnut crop once again large fluctuations in net long wave radiation was observed in comparison to bare soil, with higher net radiation over groundnut crop.

During December, the site, which was kept fallow during September, was covered with wheat crop under irrigated condition whereas the other site was having bare soil due to harvesting of groundnut crop. The incoming short wave radiation was seen to reach its maximum value (650 Wm^{-2}) at 14 hrs (Fig. 1-d). Since the crop was only 15 days old, there were not much differences in different radiation components. The reflected short wave radiation was slightly higher over wheat crop.

The 24 hr. average values of different radiation components during all the seasons are summarized in Table 2.

The incoming short-wave radiation was maximum at 920 Wm^{-2} (May) and 675 Wm^{-2} (December) respectively at the peak hour for these periods. The short wave radiation received at ground was more during May and was less in monsoon season. A 25 per cent decrease in incoming short-wave radiation was noticed from May to December (307 Wm^{-2} to 218 Wm^{-2}).

The reflected short wave radiation, was strongly affected by the plant structure, and

Table. 3 : Average (24 hrs average) energy balance components (Wm^{-2}) during four season's IOP

Components	May(grass)	July(sunhemp)	September(bare)	December(wheat)
H	60	31	42	38
L	30	58	74	12
G	42	39	30	41
Rn	132	127	146	91

Table 4 : Percentage contribution of H, L and G to net radiation.

Components	May	July	September	December
H	45	25	29	42
L	24	44	51	14
G	31	31	20	44

its density, and was lower over the cropped surface than that over the bare soil surface. It shows strong diurnal variation as the incoming short wave radiation. During May, on the short grass field, the average reflected short wave radiation was 69 Wm^{-2} per day (Table 2) and over bare surface 65 Wm^{-2}. Thus the reflectivity over short grass field was 21% which is in agrement with Kalma and Badham (1972). Albedo during monsoon periods decreased due to wetness of the soil. During September, over groundnut crop field, the crop density increased which absorbed more incoming short wave radiation and reflected less. It was in the order of 37 Wm^{-2} with surface albedo 17% whereas over bare soil surface, albedo was 23%. The result is in consonance with Sellers (1965). Results thus show the combined effect of surface wetness due to soil moisture availability (due to rain) and crop density.

Net radiation was the lowest in December over bare soil (70 Wm^{-2}) and the highest over groundnut (154 Wm^{-2}) cover in September. The net long wave radiation for bare ground was more during summer and winter seasons but for cropped surface it was higher at night. This might be due to the moderating effect of evaporative cooling on the leaf surface temperature and/or a relatively higher atmospheric emissivity due to high vapour content (Oke, 1978).

Energy budget

During summer season (May) the sensible heat flux (H) was positive during daytime with strong diurnal variation. As the

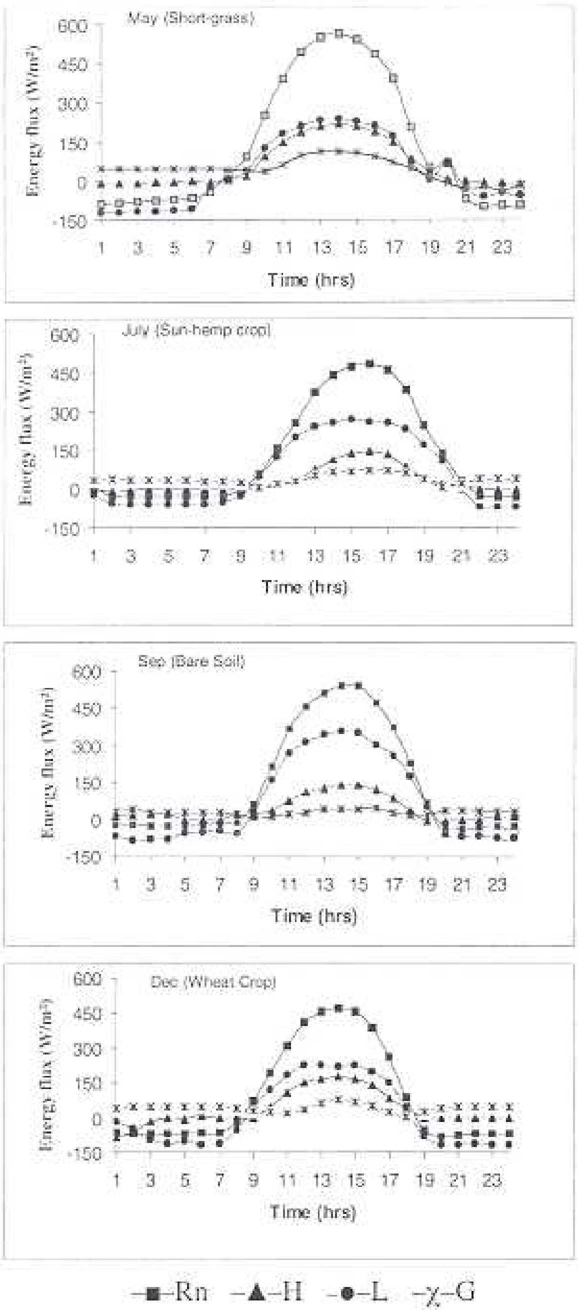

Fig. 2 : Diurnal variation of energy components under different conditions

day progressed, surface became hotter, the advection also increased with maximum sensible heat at midday (190 Wm^{-2}), at around 13 hrs. During the late afternoon hours, H was directed towards the surface due to mild advection of sensible heat (Kim *et al.*, 1989). At night when the temperature gradient was positive, the sensible heat was observed to have negative value, i.e. directed from atmosphere to the surface. The nighttime sensible heat flux was -20 Wm^{-2}. The latent heat flux was observed to be very close to sensible heat flux during summer (May). The maximum daytime latent heat flux was 200 Wm^{-2} whereas the minimum nighttime latent heat flux was -120 Wm^{-2}. The latent heat flux should be less during summer, but chilli and bajra crops were grown surrounding the tower sites and irrigation was given during those period in these plots.

During active monsoon season (July), the green manure crop sunhemp was grown near the tower; the maximum sensible heat was observed between 13 to 15 hrs with a value 120 Wm^{-2}. During this period, the nighttime H was observed to be -10 Wm^{-2}. Latent heat fluxes increased during wet condition i.e., during monsoon period. Similar result was observed during September, when the surface was bare but wet due to rains.

During winter (December) the field was covered with wheat crop with 10-11cm during the observational period. Sensible heat was more than that during the monsoon with daytime maximum of 170 Wm^{-2} and nighttime minimum -20 Wm^{-2}, respectively. Latent heat flux was also high during December.

The hourly values of radiation components for 24 hour period were averaged and are presented in Table 3. It may be seen that average net radiation was maximum (146 Wm^{-2}) during September in contrast to general belief of being in summer (May) when it was 132 Wm^{-2} followed by July 127 Wm^{-2}. During May maximum energy is in the form of sensible heat flux (60 Wm^{-2}) whereas in July and September it was latent heat fluxes 58 Wm^{-2} and 74 Wm^{-2} respectively. During winter season the ground heat flux contributed maximum (41 Wm^{-2}) in the energy balance followed by sensible heat flux (38 Wm^{-2}).

Both ground heat flux and sensible heat flux were less in monsoon but latent heat flux was more during these periods. Partitioning of net radiation into latent heat flux in monsoon months was more than in others.

ACKNOWLEDGEMENTS

The authors are thankful to the Department of Science and Technology, New Delhi, Govt. of India for funding to run LASPEX-97 successfully, and the Indian Institute of Tropical Meteorology for co-operation.

REFERENCES

Arya, S. P. S. 1988. Introduction to Micrometeorology, Academic Press Inc, NewYork.pp. 306.

Kalma, J. D. and Badham, R. 1972. The radiation balance of a tropical pasture. I. The reflection of shortwave radiation. *Agric. Meteorol.*, 23: 217-229.

Kim, J., Verma, S. B. and Rosenberg, N. J. 1989. Energy balance and water use of cereal cops. *Agric. Forest. Meteorol.*, 48 (1-2) : 135-147.

Oke, T. R. 1978. Boundary Layer Climates, Mathew & Co. Ltd., NewYork.pp. 372.

Rosenberg, N. J., Blad, B. L. and Verma S. B. 1983. Microclimate : The Biological Environment. John Wiley & Sons, NewYork.pp. 495.

Sastry, P. S. N. 1997. Evaluation of energy balance over crop surfaces. Lecture notes on Fundamentals of boundary layer Physics and its application, Jawahar Lal Nehru University, New Delhi.

Sellers, W. D. 1965. Physical Climatology, Univ. of Chicago Press. Chicago, Illinois.272 pp.