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MICROCLIMATIC STUDIES OF GRASSLANDS IN THE ARID ZONE OF NORTH-WEST INDIA

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ABSTRACT

Microclimatological studies were carried out for a period of 3 years (1976-1978) during summer, monsoon and post-monsoon seasons in the grassland sites at Chandan (Jaisalmer), Beechwal (Bikaner) and Palsana (Sikar) in the north-west arid zones of India. The percentage of net to total radiation was higher and the albedo values were the lowest during monsoon season. Radiation interception during monsoon season was the lowest at Palsana grasslands sites compared to Beechwal and Chandan. The thermal environment of grasslands of Chandan was the highest in all the seasons compared to other sites. Higher surface soil temperature (> 50°C) during mid-day hours coupled with higher canopy temperature resulted in considerable heat losses through long wave radiation.

INTRODUCTION

About 62 per cent of the Indian arid zone is distributed in the eleven western districts of Rajasthan State (Krishnan, 1968) and supports a large livestock population of 20 million (Malhotra et al., 1983). Broadly the grasslands in these areas represent the *Dichanthium*, *Cenchrus* and *Lasiurus*, out of the five major grass covers of India identified by Dabadghao and Shankarnarayan (1973). Due to increase in animal population, pressure on the grazing lands increased considerably in the recent past and also, the extremes of environmental conditions lead to desertification by depletion of the natural resources at a greater speed. Micrometeorological studies of the grasslands situated in different rainfall regions and having varied composition were taken up during summer, monsoon and post-monsoon.

Location of research sites

The observations were recorded in three protected research sites located at the Range Management and Soil Conservation Centres of CAZRI (Fig. 1). The first research site (Chandan) is 300 km north-west of Jodhpur on Jaisalmer-Pokaran highway. The normal annual rainfall of this region is below 200 mm and the soils are

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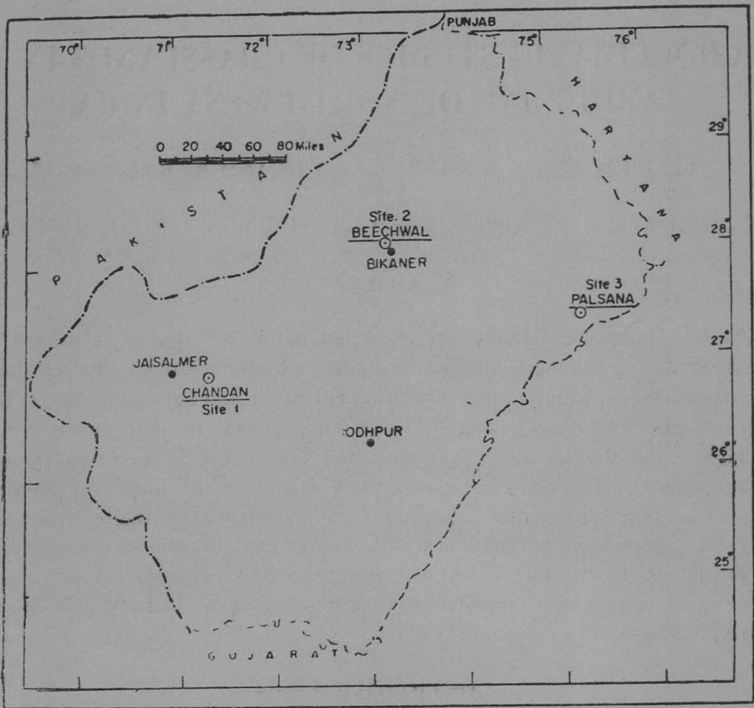


Fig 1 Location map of study area

sandy which overlie the buried pediments and *Lasiurus sindicus* is the major grass cover of this region. The second site (Beechwal) is located 300 km north of Jodhpur and is 3 km away from Bikaner. The normal annual rainfall is less than 300 mm and the sandy plains support a mixed grassland dominated with *Lasiurus sindicus*, *Cymbopogan schoenanthus* etc. The third research site (Palsana) is about 400 km north-east of Jodhpur and is located on Sikar-Jaipur highway. The normal annual rainfall of this tract is about 500 mm and the major grass species is *Cenchrus ciliaris* Higher wind speeds are observed at Chandan followed, by Beechwal and Palsana.

MATERIAL AND METHODS

Micrometeorological observations viz., total and net radiations, albedo, radiation profiles at different levels in the canopy, were recorded manually at hourly intervals from 0600 h to 1800 h on some representative days during summer, monsoon and post-monsoon seasons for the years 1976-1978 at all the three selected sites. The average value based on three-year data for each station was worked out. The hourly variations of net radiation flux (Rn) over the canopy were measured with a Funk type of net radiometer, which was mounted on a tripod stand and the total radiation was measured by a solar cell, mounted on a plastic plate with spirit level arrangements and connected to one end of a meter scale. The same instrument was used to measure the albedo and radiation profiles within the canopy. The output from the solar cell was calibrated against the output from Kipp's solarimeter mounted on the top of the climatological laboratory building of CAZRI, Jodhpur. The net radiometer was also periodically calibrated against a standard instrument in the climatological laboratory. Hourly air temperature profiles at ground level, mid canopy and above canopy, were recorded using Assman psychrometer at different heights. Hourly soil temperatures at 5, 15 and 30 cm soil depth were recorded by calibrated bent bulb thermometers permanently placed at different depths.

The energy balance at any surface can be written as

$$Rn = G + H + LE \qquad \ldots \qquad \ldots \qquad (1)$$

where Rn (Net Radiation flux) represents the heat loss and the modes of dissipation represented by G (Soil heat flux), H (Sensible heat flux), and LE (Flux of latent heat)

Soil heat flux (G) was calculated by using the equation of Rosenberg (1974) :

$$q = -K \rho C \frac{dT}{dZ} \qquad \ldots \qquad \ldots \qquad (2)$$

where q = soil heat flux ($cal/cm^2/°C$)
K = thermal diffusivity (cm^2/sec)
ρ — bulk density of the soil (g/cm^3)
C — specific heat of the soil (cal/g/°C)
dT — temperature difference
dZ — depth of increment involved

The negative values indicate downward flow of heat.

The value of K [the quotient of thermal conductivity (λ) and specific heat of soil] is written as

$$K = \frac{\lambda}{C} \qquad \ldots \qquad \ldots \qquad (3)$$

The thermal conductivity (λ) for dry sand (0.004 cal/cm/deg/sec) was used to compute K values with = 1.55 g/cm^3 and C = 0.26 cal/g/°C, since the top soil of arid region dries up quickly. Therefore, the soil heat flux values were calculated from the hourly values of surface soil temperature and at 5 cm depth.

Latent heat flux (LE) was computed by using the equation of McIlroy (1971);

$$LE = (Rn - G)\left[1 - \frac{1}{\left(\frac{\Delta}{r} + 1\right)}\right]\frac{\Delta T}{\Delta TW} \qquad \ldots\ldots \qquad (4)$$

where LE — latent heat flux
Rn — net radiation
G — soil heat flux
Δ — slope of saturation vapour pressure versus temperature curve
r — psychrometric constant

$\triangle T$ — difference in dry bulb temperature between two heights
$\triangle TW$ — difference in wet bulb temperature corresponding to the above referred heights.

The values of $\frac{\triangle}{r}$ for the respective temperatures were taken from the Technical Monograph of CAZRI, 1978 (Krishnan and Sastri, 1978).
Sensible heat flux (H) was indirectly obtained by balancing the equation (1) as

$$H = Rn - G - LE \quad \text{— ... (5)}$$

The hourly values of the above energy balance components during daylight hours were totalled to work out the dissipation of energy in different seasons.

RESULTS AND DISCUSSION

Total and Net Radiation

Grasslands in western Rajasthan receive about 12 99 x 10^7 Wm^{-2} of total radiation annually, the maximum in India. Grasslands at Chandan and Beechwal recorded higher intensities of radiation compared to Palsana (Fig. 3). The variations in the net radiation values over the three regions were, however. low, suggesting that radiation losses through long wave radiation were higher (Ripley and Redmann, 1976).

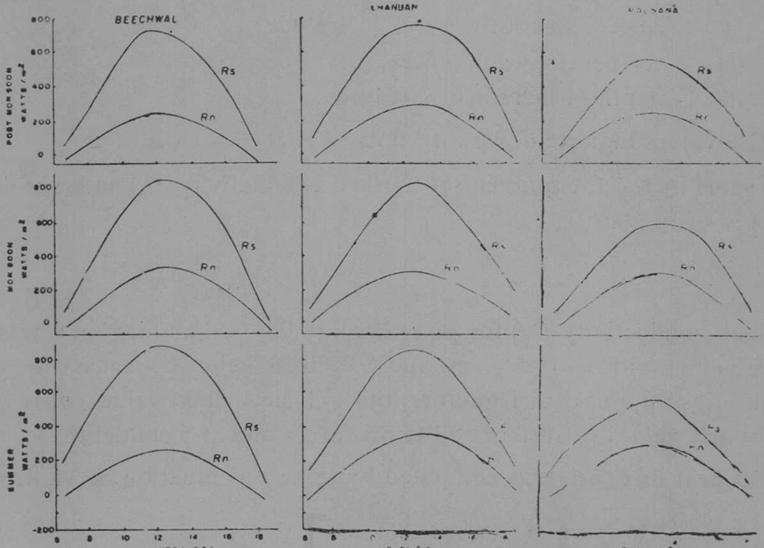


Fig. 2 : Diurnal pattern of net and total radiations over different grasslands in three agroclimatic regions

Hourly totals of net radiation plotted against hourly totals of total solar radiation for different seasons gave a nearly straight line for all the locations (Fig. 3). The non-significant morning and evening hysteresis could be attributed to higher winds and downward flux of long wave radiation during afternoon, as suggested by Ripley and Redmann (1976) for Matador grasslands. The monsoon season ratio of

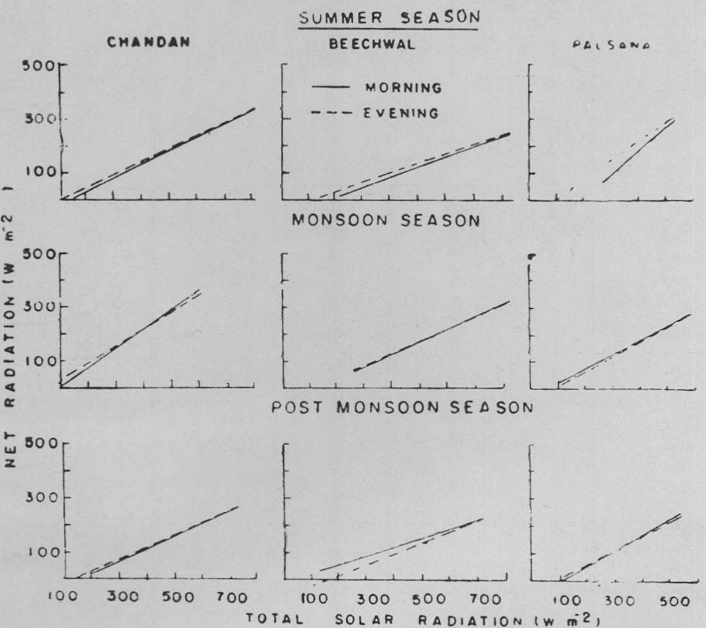


Fig 3 HOURLY NET AND TOTAL SOLAR RADIATION RELATION DURING DIFFERENT SEASONS

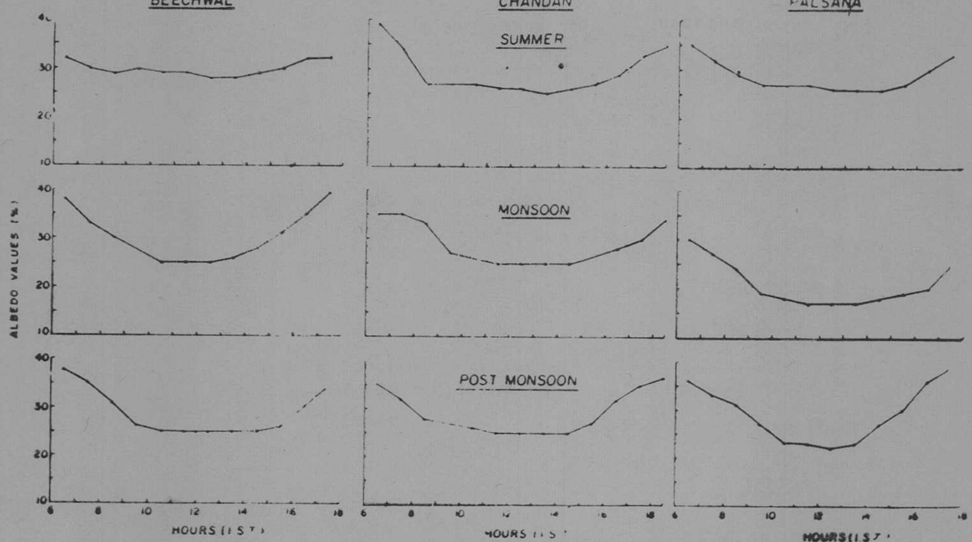
net to total radiation values were the highest at Beechwal and Chandan, and not much difference was found between summer and monsoon seasons at Palsana (Table 1). The increase in the percentage values during monsoon season could be due to the absorption of the upward flux of long-wave radiation emitted from the canopy surface high by the level water vapours in the air or due to the increased height of vegetation (Decker, 1959).

Table 1. The mean percentage values of net radiation and radiation interception at differet layers to total during mid-day hours

	Station	Summer	Monsoon	Post-monsoon
1.	Chandan	42	57	38
2.	Beechwal	39	54	32
3.	Palsana	52	50	41

Diurnal variations in Albedo

At Palsana, albedo values were less during mid day hours compared to Chandan and Beechwal during monsoon and post monsoon seasons (Fig. 4), probably due to greater coverage of ground by the annuals and also prolonged growing season with plants remaining green in the post-monsoon period also. A dish-shaped curve with minimum value 25 at Beechwal and Chandan and 17 at Palsana during afternoon hours of the monsoon season was observed. In summer season, the albedo values at Beechwal were almost constant throughout the day due to cloudy skies. However, at



F'' 4 DIURNAL VARIATIONS OF ALBEDO VALUES (%) AT DIFFERENT SEASONS

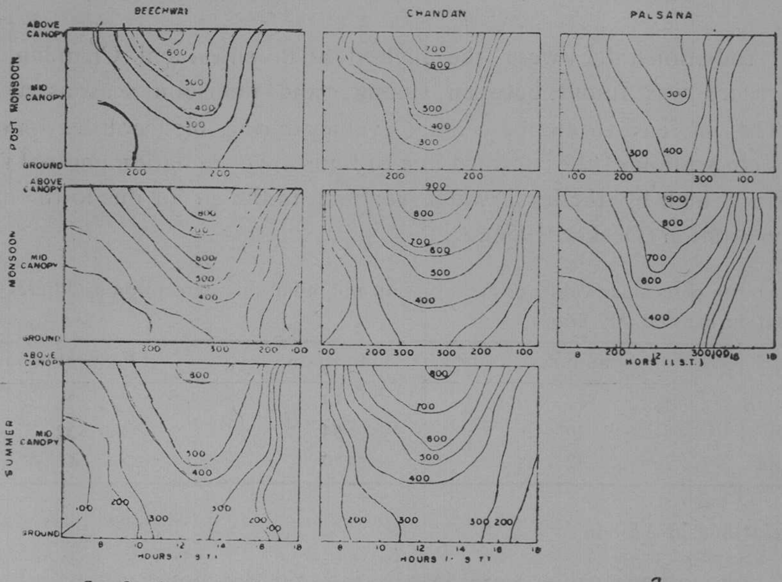


Fig 5 Radiation distribution in different layers (W m^{-2})

the other two stations, the noon values were about 26 to 27 per cent. Krishnan and Rao (1978) reported the albedo values to increase in the *Lasiurus sindicus* grasslands from 20 to 28 per cent in the growing season to 30 to 34 per cent in other seasons.

Radiation interception

High radiation values ($600 Wm^{-2}$) were recorded during mid day hours at top canopy level with higher values recorded during summer and post-monsoon season at all the stations (Fig. 5). Palsana, with erectofile cover of *C. ciliaris* grass, had higher mid-day radiation penetration values upto the ground level than the other two places during monsoon and post-monsoon seasons. The average values of percentage radiation interception in the layer between bottom to mid canopy (I layer) and mid canopy to top of canopy (II layer) are shown in Table 2. Radiation interception at both the layers during monsoon season was higher at all the places due to better plant growth. The grasslands at Beechwal recorded highest intercepted radiation values during monsoon season due to the nature of mixed grassland type with the composition of different grass species like *Aristida funiculata, Dactyloctenium sindicum* etc. The intercepted values were lower at Palsana as the grassland at this station were not so dense as compared to Chandan and Beechwal and their aerial extent was also low. It was interesting to note that even during summer season, when the grasses were usually dry, about half of the incident radiation was intercepted by *Lasiurus sindicus* grass clumps at Chandan and Beechwal and the mat of dead vegetation neai the ground became very hot due to the absorption of this radiation.

Table 2. Radiation interception (%) at different layers of canopy (I layerbottom to mid conopy, II layermid to top of canopy)

Station	Layers	Summer	Monsoon	Post-monsoon
Beechwal	I	23	41	35
	II	48	75	61
Chandan	I	29	34	31
	II	56	60	55
Palsana	I	—	37	16
	II	—	59	38

Thermal environment

The temperature profiles within the canopy and below the soil (upto 30 cm depth) during summer, monsoon and post monsoon, respectively, are presented in Fig. 6. The canopy temperature was generally high in the mid to lower regions at all the stations. The grasslands of Chandan were comparatively warmer in all the seasons. Conopy temperatures increased at all the stations after monsoon season. Dry vegetation components of the grassland lose most heat to the surrounding air only by sensible heat transfer and thus make canopy the warmest region. During monsoon, even though available radiation values at different layers at palsana were comparable with the other two stations, the grasslands were cooler by 6° to 8°C. The annual grass species like *Eragrostis ciliaris, Indigofera cordifolia, Pupalia lappacea*

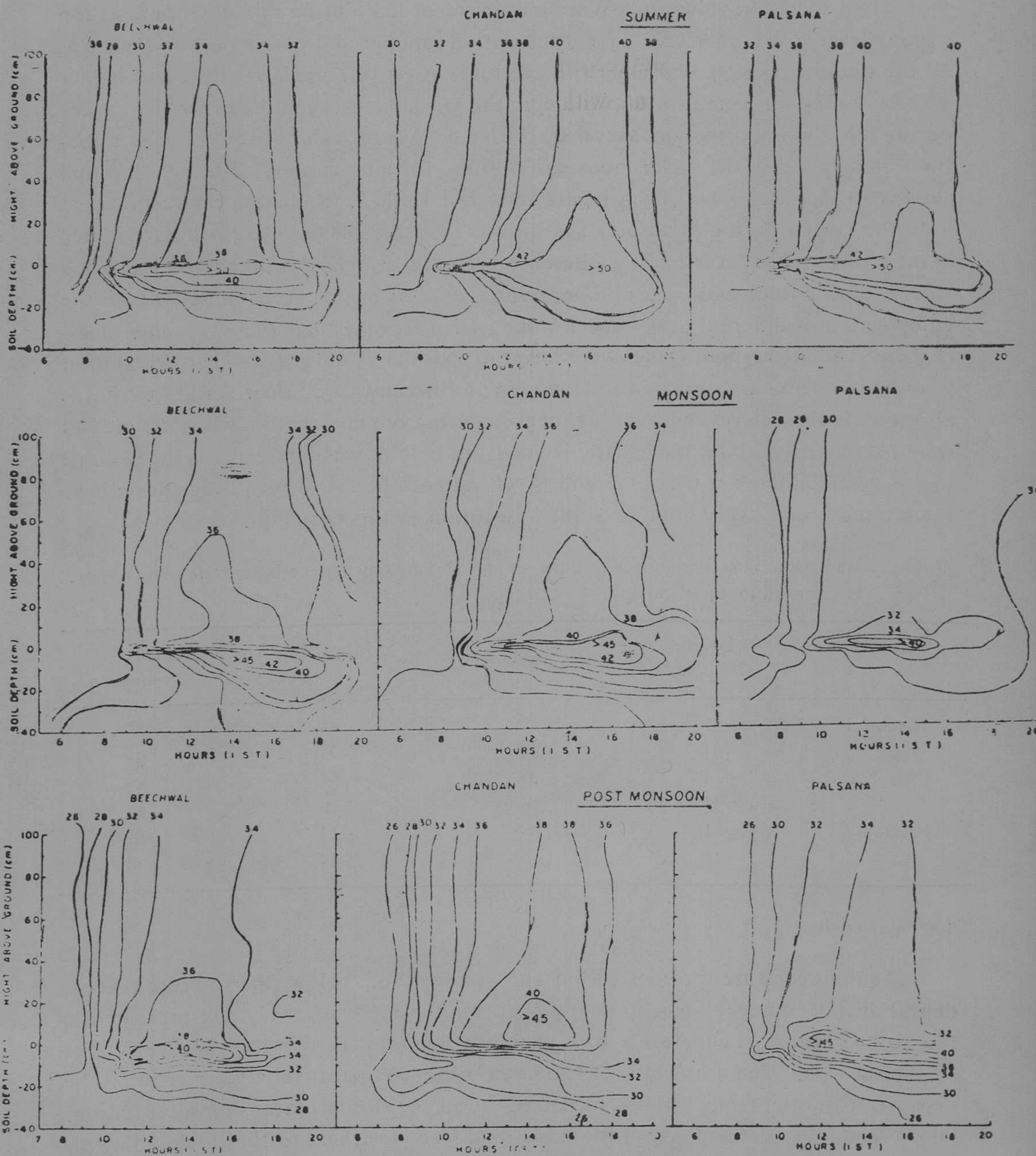


Fig. 6. Soil and air temperature profiles during different seasons

etc. completely covered the ground. Transpiration by these annuals might have caused lower temperatures. After the completion of the life cycle of the annuals, increase of 2° to 4°C in the canopy temperature was observed in post-monsoon period.

The surface soil temperature during the mid-day hours in the summer season ranged between 54 to 63°C at these grasslands. However, during monsoon and post-monsoon season, it ranged between 35° to 56°C and 35° to 57°C. The high surface temperature (50°C)of the grasslands, coupled with higher canopy temperature, results in considerable heat losses through upward flux of longwave radiation. This would effect the overall radiation balance of the ecosystem by registering lower amounts of net available energy.

Energy balance of grassland sites

The courses of various energy balance components during daylight hours calculated from energy balance method for summer, monsoon and post-monsoon seasons are shown in figures 7, 8 and 9 respectively. The diurnal course of LE, G and H followed the same course of total and net radiation flux densities. Major portion of the energy appeared to be used towards evapotranspiration (LE) during all the seasons. However, Ripley and Redmann (1976) observed that during day, energy towards sensible heat flux was higher for Matador grasslands. The average energy balance parameter totalled for the daylight hours (Table 3) showed that on the average, during monsoon and post-monsoon seasons, the energy for heating the soil and atmosphere accounted for approximately 32 to 33, 38 to 40 and 31 to 36 per cent of the net radiant energy at Chandan, Beechwal, and Palsana, respectively, and the rest was utilised toward evapotranspiration. During monsoon season, negligible amount of Rn accounted towards soil heat flux at Beechwal and Palsana due to better soil moisture conditions, whereas at Chandan, about 17 per cent of Rn contributed towards soil heat flux due to quick drying of the sandy top soil. Both soil heat flux and sensible heat flux contributed to 30 per cent of Rn, hence, the thermal environment of grasslands at Chandan was hotter compared to Beechwal and Palsana even during monsoon season.

The long wave radiation flux (Rlw) emitted by the grasslands during different seasons was estimated from total, net radiation and albedo percentage values. Other than in the monsoon season (summer and post-monsoon), the average net radiation flux during daylight hours amounted to 36 to 47 per cent of total radiation flux values and the albedo values varied between 26 to 29 per cent. The remaining part of total radiation (24 to 38 per cent) was lost as long wave radiation from these grasslands. Rosenberg (1974) also indicated the ratios of net total radiation to be low over desert regions, since short wave reflectivy of light coloured material is high as are the surface temperatures. Even during monsoon, the net long wave radiation losses accounted to greater than 30 per cent of total radiation.

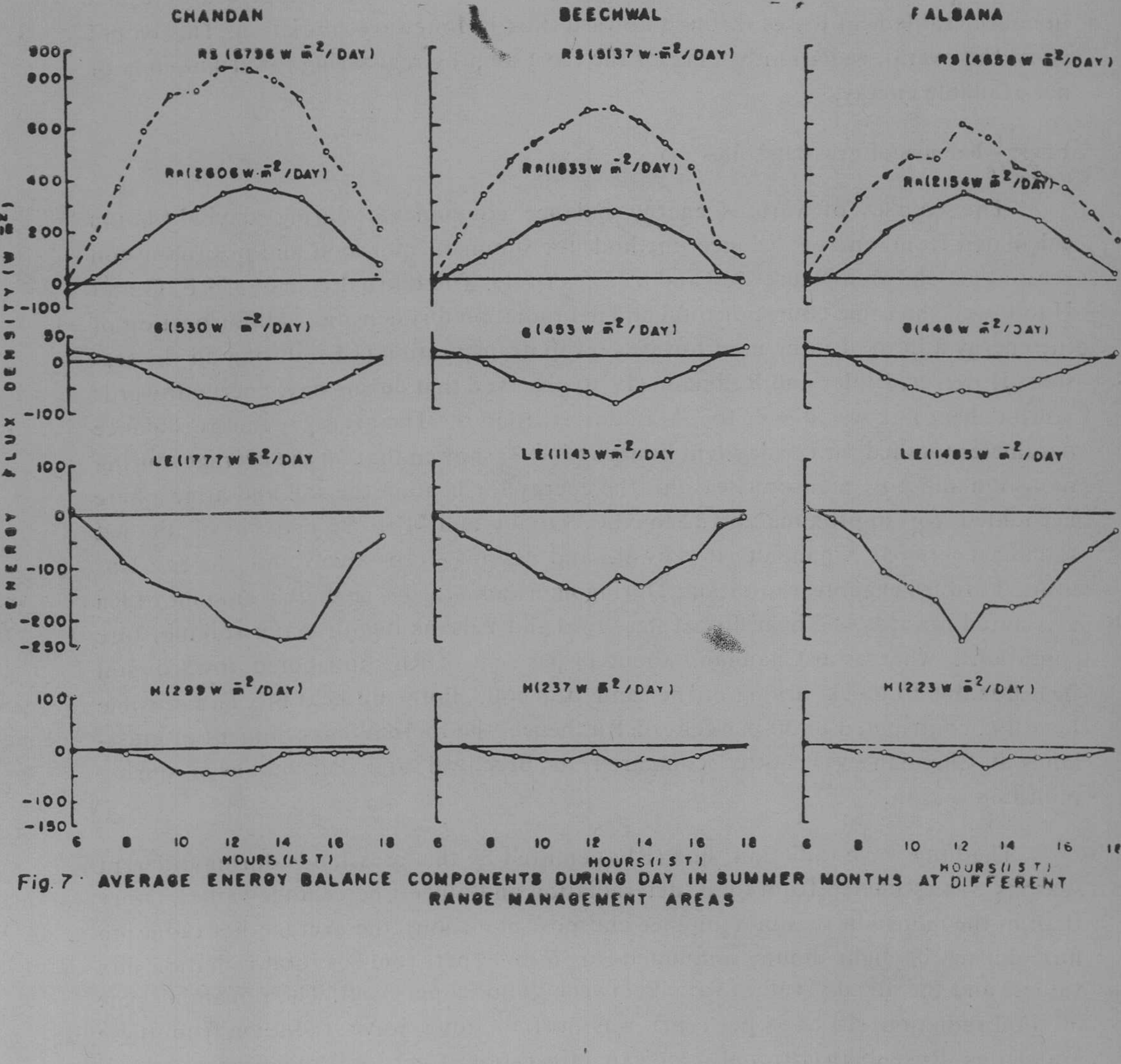


Fig. 7 AVERAGE ENERGY BALANCE COMPONENTS DURING DAY IN SUMMER MONTHS AT DIFFERENT RANGE MANAGEMENT AREAS

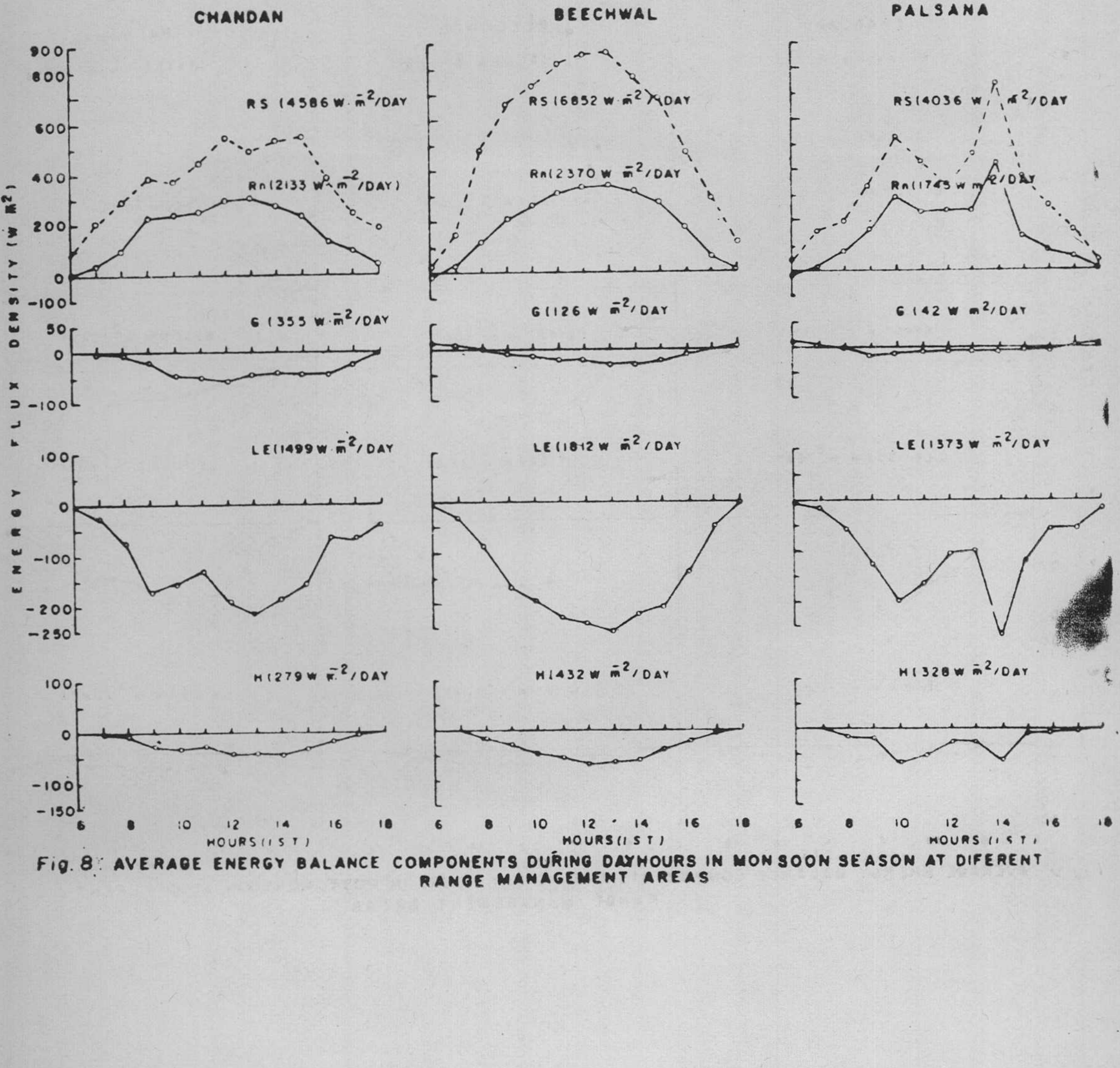


Fig. 8 : AVERAGE ENERGY BALANCE COMPONENTS DURING DAYHOURS IN MONSOON SEASON AT DIFERENT RANGE MANAGEMENT AREAS

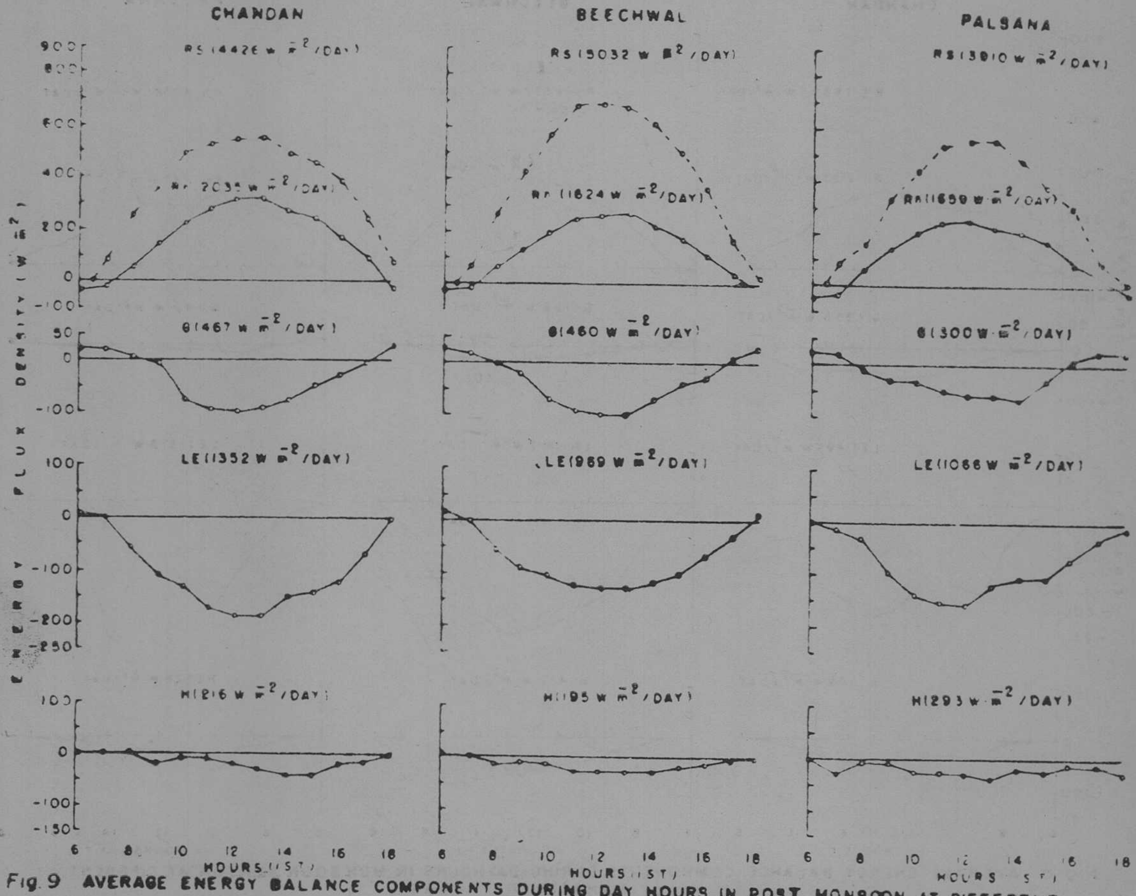


Fig. 9 AVERAGE ENERGY BALANCE COMPONENTS DURING DAY HOURS IN POST MONSOON AT DIFFERENT RANGE MANAGEMENT AREAS

Table 3. Average energy balance components ($W m^{-2}$ day) during day hours at the three locations in different seasons

Season	Chandan					Beechwal					Palsana				
	Rs	Rn	LE	G	H	Rs	Rn	LE	G	H	Rs	Rn	LE	G	H
Summer	6976	2606	1777	530	299	5137	1833	1143	453	237	4588	2154	1485	446	223
			(68)	(20)	(12)			(62)	(25)	(13)			(69)	(21)	(10)
Monsoon	4586	3133	1499	355	279	6852	2370	1812	126	432	4036	1743	1373	42	328
			(70)	(17)	(13)			(70)	(5)	(18)			(79)	(2)	(18)
Post-monsoon	4426	2025	1352	467	216	5032	1624	969	460	195	3910	1659	1066	300	293
			(66)	(23)	(11)			(60)	(28)	(12)			(64)	(18)	(18)

Rs—short wave radiation, Rn—net radiation, LE—latent heat flux, G—soil heat flux H—sensible heat flux

Figures in parentheses are percentage values to net radiant flux

It can be concluded that, on the average, the grasslands emit 30 to 40 per cent of the incident radiation from the grass canopy and its intervening soil surface in the form of long wave radiation during day light hours. The process continues during night time also and results in cooling at a faster rate. Thus the range of temperature remains very large at these grassland sites during most of the time.

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