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Efficiency of Energy Capture in Some Tropical Grasslands at Kanpur, India

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The present paper deals with the efficiency of energy utilization of sun light by protected, semi-protected and open-grazed grasslands at Kanpur. The highest efficiency values were obtained in August on protected site (8.1%) and in September on semi-protected (4.3%) and open-grazed (2.9%) sites. Annual efficiency of protected stand was (1.8% which was one-and-a-half and three times higher than those of semi-protected and open-grazed stands respectively. Significant positive correlations were found between monthly precipitation and efficiency of energy utilization on each of the three grassland sites.

Key Words: Biomass, Efficiency of energy capture, Incident solar radiation, Net primary production

Introduction

The ability of green plants to convert solar energy into chemical energy, constituting the source of food for all the heterotrophs, is of prime importance in the function of all ecosystems. Therefore, an ecologist interested in energetics is primarily concerned with the quality of solar energy per unit area of the ecosystem and the efficiency with which the energy is converted by organisms into other forms (Phillipson 1969). Plant species differ in efficiency of energy utilization because of difference in leaf morphology, leaf area, leaf orientation and the ratio of photosynthetic to non-photosynthetic biomass. Other factors which may influence the efficiency are dominant photosynthetic pathways (C-3, C-4 or CAM), the effective pigment level (Sims & Singh 1971), canopy density, intra and inter-specific interactions, light and moisture profiles, temperature and CO_2 concentration (Wassink 1968, Sims & Singh 1971). The present communication reports the efficiencies of energy utilization by certain grassland communities of Kanpur.

Study Sites

Location and physiography: Three sites were selected for the present study: site I is under long term protection from grazing, site II is protected seasonally and site III is open to grazing all the year round. Cattle stocking rates have averaged 2.3 and 1.2 acres/animal unit month for sites II and III respectively. All the sites are located on a plain topography near the Kanpur metropolitan city (26° 26′ N latitude and 80° 22′ E longitude) at an altitude of 124 m above sea level. The soil is a deep alluvial deposit of the river Ganga. It is pale brown in colour and sandy loam in texture, with a *p*H of 7.5.

Vegetation: The number of species recorded for each site were : protected (site I). 39; semi-protected (site II), 45; and open-grazed (site III), 62. *Heteropogon contortus* (L) P.B. Eams with importance Value Index (I VI) ranging from 56.3 to 100.4 on protected and 41.7 to 68.4 on semi-protected is the dominant species on respective sites. This species comprises about 22% density and 35% cover of the total vegetation on the former and 14% density and 27% cover on the later site. Other plants such as *Apluda mutica* L. and *Seteria verticillata* (L.) P. Beauv. among the annuals and *Bothriochloa pertusa* (L.) A. Camus; *Cenchrus ciliaris* L. and *Dichanthium annulatum* stapf. among the perennials occupy considerably higher index on these sites. On the other hand *Tephrosia hamiltonii* Drumm with IVI ranging from 13.8 to 56.6 and comprising 7% density and 16% cover is the dominant species on open-grazed site. Other species associated with *T. hamiltonii* in decreasing order of IVI are *Convolvulus pluricaulis* Chois; *Cassia tora* L.; *Desmodium triflorum* Dc.; *Euphorbia hirta* L.; *Tragus biflorus* Schult, and *Tribulus terrestris* L.

Climate: The climate of the area is typically monsoonic, characterized by a warm wet rainy season (July to October) followed by a cool dry winter season (November to February) and hot dry summer (March to June). Mean annual rainfall amounts to 912 mm, most of which (84%) is received during the rainy season. Mean maximum temperature varies from 22.2° C (January) to 41.2°C (May) and mean minimum temperature ranges from 7.6°C (January) to 28.3°C (June). Humidity is minimum during April (26%) and maximum during August (81%). Wind velocity fluctuates between 2.5 km/hr (November) to 8.2 km/hr (May) and atmospheric pressure between 983 Mb (July) to 1002 Mb (December). Day length ranges from 10 hr ous during winter to 14 hr in summer.

Solar radiation: Average mean of solar radiation data for the study area are given in table 1. There is a consistent decrease in the value of incident solar radiation from June (4770 Kcal/m^2/day) to January (3325 Kcal/m^2/day). Thereafter the value increases to a maximum in April (5750 Kcal/m^2/day). The mean yearly solar radiation is 16.16×10^5 Kcal/m^2. The minimum average daily radiation ocours

Table 1 *Rainfall and incident solar radiation* in different months*

Month	Rainfall (mm)	Incident solar radiation (Kcal/m^2/day)
July	243.2	4613
August	189.1	3953
September	246.1	4083
October	72.4	4480
November	—	3748
December	—	3410
January	0.5	3325
February	15.0	4320
March	—	4860
April	—	5750
May	—	5680
June	145.7	4770

*Data obtained from the Director General of Observatories, Poona, India during the winter season (1850.2 cal/cm^2) and maximum during summer season (2632.5 cal/cm^2)

Materials and Methods

Assessment of the amount of energy utilization involves determination of amount of biomass present throughout the year in aboveground and belowground compartments and of the energy content of this material. Since the semi-protected (site II) and open-grazed (site III) areas refer to grazing during the previous years and also during current year, hence grazing and data collection were concurrent.

Aboveground plant biomass (live+dead) on all the sites was estimated by harvest method at monthly intervals from June 1975 to June 1976, using 5 plots for each of the two replicates on each sampling date. The size of the harvest plot was 25×25 cm and clipping was done at the ground level. Belowground biomass was evaluated by excavating monoliths of 25×25×30 cm. The sample frequency was the same as for the aboveground biomass. Monoliths were soaked in water overnight and then washed gently with a fine jet of water using a 32-mesh screen. All the samples thus collected were dried in hot air oven at 80°C for 48 hr and weighed.

The net primary production of aboveground and belowground plant parts was calculated from the difference between the biomass values on successive sampling dates. The summation of aboveground and belowground net production yielded the estimate of net community production. The net community production in terms of energy was calculated by multiplying the net dry matter production (g/m^2) with the respective calorific value estimated by oxygen bomb calorimetry.

Efficiency of energy utilization was calculated as the percentage of usable solar radiation (50% of total solar radiation, see Terrien et al. 1957, Daubenmire 1959, Nichiporovich 1967) incorporated in primary production. Although the efficiency of energy utilization should be based upon the actual amount of light intercepted by the canopy (Botkin & Malone 1968), no data on the interception and albedo were available for the study sites. Therefore, the efficiency was based on the usable solar radiation. Efficiency values have been calculated for each month of the year on each of the three study sites. The measurements of efficiency during present study do not account for losses due to herbivory (insects, rodents, cattle etc.)

Results and Discussion

The data in table 2 indicate a contrasting behaviour of the efficiencies on the three study sites. Efficiency ranged from 0.2% to 8.1% for protected, 0.2% to 43% for semi-protected and 0.1% to 29% for open-grazed site. The Maximum efficiency was recorded in August on protected stand while in September on semi-protected and open-grazed stands. On an annual basis, the efficiency of protected site (1.8%) was one and a half and three times higher than that of the semi-protected (1.2%) and open-grazed (0.6%) sites respectively. The efficiency is related to the amount of rainfall in different months, according to the regression: $Y=0.0224\ X+0.1880$ on protected, $Y=0.0097+0.4585$ on semi-protected and $Y=0.0076\ X+0.0079$ on open-grazed area. Where, Y=efficiency of energy capture and X=amount of rainfall in different months. The relationship shows significant positive correlation on each of the three study sites ($r=0.83$, $P<0.01$ on site I; $r=0.68$, $P\leqslant0.02$ on site II; and $r=0.84$, $P\leqslant0.01$ on site III).

Compared to other studies, the efficiency of present grassland (ranging from 0.6% to 1.8%) is above average. Growing season

Table 2 *Net community production (NCP g/m²) and efficiency of energy capture (EEC percentage) for three grasslands* (—nie)

Month	Protected		Semi-protected		Open-grazed	
	NCP	EEC	NCP	EEC	NCP	EEC
July	20.0	3.4	9.2	1.7	5.5	0.9
August	29.8	8.1	13.6	3.4	8.0	1.6
September	14.5	5.6	12.8	4.3	9.3	2.9
October	9.5	2.2	5.8	1.5	4.3	0.4
November	—	—	—	—	—	—
December	—	—	—	—	—	—
January	—	—	—	—	—	—
February	10 0	1.9	9.7	2.8	4.3	0.7
March	—	—	—	—	—	—
April	—	—	—	—	—	—
May	—	—	—	—	—	—
June	2.3	0.2	2.0	02	1.5	0.1

efficiencies ranging from 0.4% to 0.7% (based on energy within the visible spectrum and total plant net production) were determined by Old (1969) for an Illinois prairie. On the same basis efficiency of 1.2% was found by Kucera et al. (1967) in a tall grass prairie in Missouri. A comparison with the data of Moir (1969) and Sims and Singh (1971) indicates that the efficiency of energy utilization in the present grassland is much greater than the temperate grasslands. This is in accord with Black (1971) and Singh and Yadava (1974) who explain that because of the preponderance of C_4 plants and occurrence of year long growth and a dynamic-multilayered canopy, the tropical grasslands are more efficient in energy utilization as compared to their temperate counterparts.

Recently, Singh and Joshi (1977) reviewed research on potential production and energy conversion of 13 grasslands in India. They found that the energy converted during the year may range from 0.2% for the semi arid grassland at Pilani to 1.7% for dry sub-humid grassland at Kurukshetra. The efficiency of presently studied grassland expressed on percentage basis ranged from 0.6 to 1.8 lowest was obtained for open-grazed site which is probably due to the reason that the aboveground plant parts taken away by the grazing animals have not been considered.

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