EFFICIENCY OF ENERGY CAPTURE BY THE GRASSLAND VEGETATION AT VARANASI

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WITH the growing interest in recent years on the evaluation of productivity in various natural and man-modified ecosystems, much emphasis has been laid on the efficiency with which the energy is trapped, accumulated and dissipated at different trophic levels. The first step in the process of energy flow within an ecosystem is the capture of solar energy by green plants. The productivity potential of different ecosystems depends much on the efficiency with which the vegetation accumulates this energy in the net primary production. Although data on energy relations of a number of temperate ecosystems have been published,[1-6] so far no information is available regarding the terrestrial systems in India.

The present study was conducted with three types of grasslands situated within the campus of the Banaras Hindu University (25° 20′ N. latitude 83° 1′ E. longitude). These grasslands are graded according to the intensity of herbage removal as least disturbed, moderately disturbed and over disturbed.[7] Net aboveground community production was evaluated through monthly harvests and by summing up the positive differences in the plant biomass in different periods.[7] Underground plant biomass was evaluated through monoliths and net production was computed by the difference method.[8] Energy content of the aboveground and underground plant material was estimated with the help of a Bomb calorimeter during June 1968.[9] The calorific values were calculated on the basis of ash-free dry weight in order to avoid the variation between organic samples of various types and the error due to pollution with dense, non-combustible materials as argued by Ovington and Lawrence.[5]

The energy content varies from 4018·8 to 4356·6 gram cal./g. ash-free dry weight in the aboveground parts of the herbage and from 4528·1 to 4770·4 g.cal./g. in the underground parts. The average values based on six samples of aboveground herbage and three samples of underground plant material come to 4150·23 g.cal./g. and 4648·06 g.cal./g. respectively. Ovington and Lawrence[5] have reported the following calorific values for maize field, prairie, savanna, and oakwood ecosystems in Minnesota: 4525, 4827, 4817 and 4865 g.cal./g. respectively. Thus, the energy content in the herbage of our grasslands seems to be a little lower than that of temperate vegetation. In alpine plants, Hadley and Bliss[10] have reported higher calorific values for shoots (4557–5648 g.cal./g.) as compared to underground parts (4405–4996 g.cal./g.). In our grasslands the situation is reverse.

On the basis of the calorific values and the net dry matter production, the net primary community production in different grasslands has been computed in terms of energy and the values for the same are set in Table I. From Table I it is apparent that most of the net annual energy accumulation is accrued during the period 23rd June to 30th September, which, therefore, constitutes the grand period of growth. The new underground growth during post-monsoon period could not be measured because it is very meagre as compared to the decomposition and disappearance of the carry over from the monsoon period. Evidently, therefore, more thorough sampling gadgets and procedure have to be used in future studies.

The amounts of energy in the primary net production when expressed as percentages of half of the total solar radiation received during the period represent the efficiency of energy capture. Here only half of the incident radiation is considered because approximately 50% of the total radiation (that in the ultraviolet and infra-red portions of the spectrum) is not usable by plants in photosynthesis.[11,12] No data on incident solar radiation are available at Varanasi, but at Allahabad, which is situated very near to this area on almost the

TABLE I

Net primary production in the grasslands at Varanasi in terms of energy (kg.cal./m²)

Grasslands	Aboveground		Underground		Total annual net production	
	June–September	Total annual	June–September	Total annual	June–September	Total annual
Least disturbed ..	1449·72	1798·30	1436·11	1436·11	2885·83	3234·41
Moderately disturbed ..	1822·78	2105·41	1193·39	1193·39	3016·17	3298·80
Over disturbed ..	1958·91	2139·44	990·96	990·96	2949·87	3130·40

TABLE II

Efficiency of energy capture as percent half total solar incident radiation

Grasslands	Aboveground		Underground		Total annual net production	
	June–September	Total annual	June–September	Total annual	June–September	Total annual
Least disturbed ..	0·82	0·19	0·81	0·15	1·63	0·34
Moderately disturbed ..	1·03	0·22	0·67	0·12	1·71	0·35
Over disturbed ..	1·11	0·23	0·56	0·10	1·67	0·33

same latitude, 511 g.cal./cm.²/day have been recorded as average incident solar energy. Thus, total incident solar radiation for the year comes to 1865150 kg.cal./m.² and that for the grand growth period (23rd June to 30th September) 352590 kg.cal./m.² The data for the efficiency of energy capture based on 50% of these values are set in Table II.

It is apparent from Table II that the progressive disturbance increases the net production and efficiency of aboveground parts and decreases these for the underground parts. It implies, therefore, that in comparatively protected fields energy is stored in the underground parts with greater efficiency, while with increasing disturbance more energy is accumulated in aboveground parts. The efficiency is more than five times greater during June–September as compared to the average efficiency for the whole year. When the total net production (aboveground + underground) is considered the differences in the efficiency due to variable intensity of disturbance become meagre. The results indicate that even during the grand growth period only 1·63–1·71% of the usable solar insolation is accumulated by the vegetation.

Ovington and Lawrence[5] have reported the efficiency of energy capture by the maize field, their most productive ecosystem, to be 0·94% for the growing period of 92 days and 0·35% for the whole year. Evidently, they have considered total incident solar radiation. Based on the same type of consideration average efficiency for our grasslands would be 0·83% and 0·17% respectively for the grand growth period and for the whole year. For an old-field Broomsedge Community at South Carolina this efficiency is reported by Golley[4] to be 0·3–0·4%. But instead of net production he has considered gross production and hence no direct comparison can be made.

Based on the average annual input of solar radiation and dry matter yield of cereals, Penman[13] has recently estimated this efficiency for certain tropical countries including India to range between 0·02 and 0·04%.

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