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ENERGY FLOW INTO PRIMARY PRODUCERS OF PROTECTED AND GRAZED GRASSLAND ECOSYSTEMS AT VARANASI (India)*

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RESUME

Le flux d'énergie et le rendement de l'énergie fixée annuellement ont été établis pour des écosystèmes herbacés mis en protection et pâturé. Ces écosystèmes, situés à Bénarès (25°18' de latitude N, 83°1' de longitude E), en Inde, sont dominés par D i c h a n t h i u m a n n u l a t u m. Ils fixent 4,98 et 0,99 Kcal.m^{-2}.jour^{-1} selon qu'ils sont mis en protection ou pâturés. Les flux d'énergie correspondant à la décomposition de la litière et à celle de la biomasse hypogée ont été estimés respectivement à 1,04 et 2,90 Kcal.m^{-2}.jour^{-1} pour les parcelles protégées et à 0,33 et 4,09 Kcal.m^{-2}.jour^{-1} pour les parcelles pâturées. Le taux annuel de conservation d'énergie est de 0,805 et 0,626 %, selon que les écosystèmes herbacés sont mis en protection ou pâturés.

ABSTRACT

The energy flow and the annual energy conserving efficiency into primary producers were established, in both protected and grazed grassland ecosystems, dominated by D i c h a n t h i u m a n n u l a t u m, at Varanasi (25°18' N latitude and 83°1' E longitude), India. The grassland ecosystems captures energy at a rate of 14.15 Kcal/m^2/day under protected condition and 11.39 Kcal/m^2/day under grazing pressure. The transfer of energy flow from standing live compartment to standing dead compartment occurs at the rate of 4.98 Kcal/m^2/day and 0.99 Kcal/m^2/day on protected and grazed grasslands, respectively. The rate of litter and underground disappearance were 1.04 Kcal/m^2/day and 2.90 Kcal/m^2/day on protected, 0.33 Kcal/m^2/day and 4.09 Kcal/m^2/day on grazed grasslands. The annual energy conserving efficiency of protected and grazed grasslands was 0.805 per cent and 0.626 per cent, respectively.

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INTRODUCTION

The ultimate source of energy is the solar radiation which is trapped by autotrophs and is converted into chemical energy (LINDEMAN, 1942). In grassland ecosystem the aboveground plant parts represent the major primary producers; they are the agents mainly concern in transferring the solar radiation into chemical energy, which is stored in the form of various organic substances. The first step in the process of energy flow within an ecosystem is capture of solar energy by green plants. The growth of the plant body and the interconversion of organic matter within, use up a part of the energy in respiration which maintains the structure. Productivity potential of different ecosystems, depends upon the efficiency with which energy is accumulated and transferred in different trophic levels. The present study deals with the impact of grazing on the energy flow into primary producers and energy conserving efficiency of grassland ecosystems dominated by *Dichanthium annulatum* (FORSK.) STAPF. at Varanasi.

THE STUDY AREAS

Site.

The present study is confined to the fields situated in the campus of Banaras Hindu University which is about 5 kilometers south from Varanasi (25°18' North latitude and 83°1' East longitude). It is situated on the upper Gangetic plains towards the west bank of the river Ganges. It is approximately 79 metres above the sea level. Sixty two years before the establishment of this University, this area was under agricultural and industrial practices. The general vegetation at that time was characteristic of the surrounding country. The present reminents are in the form of groves, mounds and ponds. Many fields are left abandoned and revert to grassland on account of continuous grazing. Since the conditions for growth are favourable all round the year, these fields never remain denuded.

For the present study two types of grasslands were taken i.e., completely protected for one year (protected grassland) and open grazed (grazed grassland). The first plot was situated in the Botanical garden. This protected field was fenced by iron-wire since May 1975. It was not allowed to be biotically disturbed. The grazed grassland was situated near the Agricultural farm. It was open for grazing by diary farm's animals, local villagers' animals and animals of Banaras Hindu University Staff. The main grazing animals were cows, buffaloes and goats.

Climate.

The climate is typically monsoonic, which is characterized by three distinct seasons i.e. rainy, winter and summer. The average annual rainfall was 902.3 mm of which about 89 per cent was recorded in rainy season. The mean annual relative humidity, maximum and minimum temperature were recorded 63.1 per cent, 33.3°C and 21.2°C, respectively. Recording centre of solar radiation data at Varanasi is not available. Data for Patna, which is the nearest station, are of 1.295.210 Kcal/m^2/year (July 1976 - June 1977).

METHODS

Biomass values of different component in different months have been determined by harvest method, they were multiplied by the caloric values of plant material, calculated as method suggested by LIETH (1968). Thus energy structure has been obtained. Aboveground net production has been accounted by summing the total positive changes in the aboveground live biomass on successive sampling dates throughout the year, plus positive changes in standing dead and litter biomass for only those sampling intervals during which a positive difference also occurred in aboveground live biomass. The standing dead, litter and underground net production have been estimated by the positive increases in biomass on successive sampling dates throughout the year. The litter disappearance (LD) has been estimated as per method given by SINGH and YADAVA (1974).

$$LD = (\text{Initial litter} + \text{litter production}) - \text{litter of the end}$$

The underground disappearance is represented by the summation of negative changes in the energy structure of underground parts. Total net production is the sum of above ground net production and underground net production, total disappearance is also sum of litter disappearance and underground disappearance. The energy conserving efficiency has been calculated usign the following formula :

$$\text{Energy conserving efficiency (\%)} = \frac{\text{Energy capture}/m^2/t}{1/2\ \text{solar radiation}/m^2/t} \times 100$$

with t = period of solar radiation and energy capture.

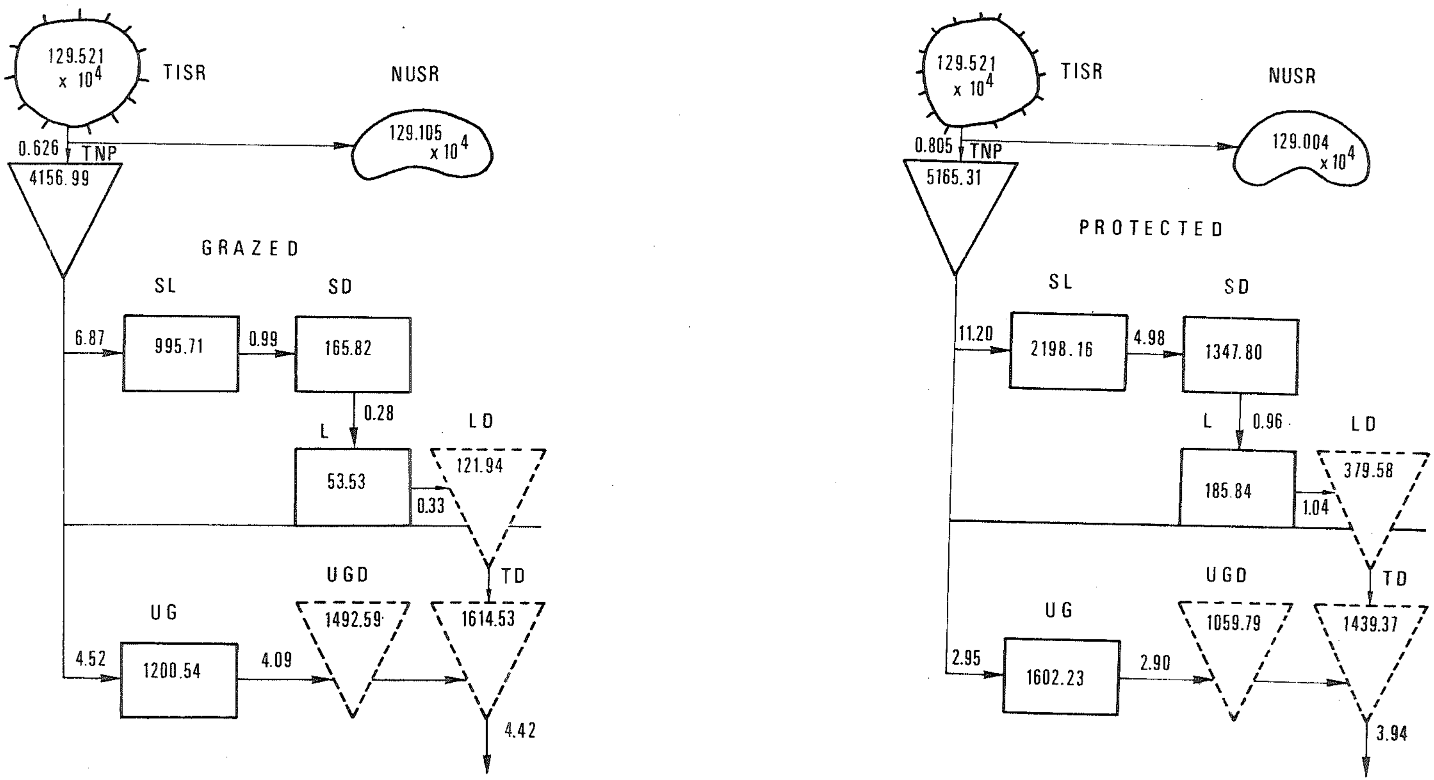

Fig. 1 : Energy flow through the primary producer compartment of grassland ecosystems. Values in compartments are average standing crop of energy (Kcal/m^2), values on arrows are flow rate (Kcal/m^2/day), values in triangles are total annual production disappearance, total incident solar radiation and not utilized solar radiation are (Kcal/m^2/year), energy conserving efficiency in percentage. TISR = total incident solar radiation, NUSR = not utilised solar radiation, TNP = total net production, SL = standing live, SD = standing dead, L = litter, LD = litter disappearance, UG = underground, UGD = underground disappearance, TD = total disappearance.

In the present study, only half of the incident solar radiation is used for calculating energy conserving efficiency because about 50 per cent of the total incident solar radiation is ultra-violet and infra-red portion of the spectrum which is not utilized by plants in photosynthesis (TERRIEN & al., 1957; DAUBENMIRE, 1959; NICHIPOROVICH, 1967). The green portion of the plant captures the energy but the material so built is distributed to other plant parts. Therefore, energy conserving efficiency of the total community has been considered with the help of aboveground and underground production.

RESULTS AND DISCUSSION

The energy captured by the vegetation through its photosynthetic process moves to different vegetation components and to other trophic levels and is ultimately dissipated from the system through respiratory metabolism of organisms of various trophic levels. The grassland ecosystem captured energy at a rate of 14.15 Kcal/m^2/day under protected condition and 11.39 Kcal/m^2/day under grazing pressure (Fig. 1). Protected grassland fixed energy 0.40 per cent and grazed grassland 0.32 per cent of total incident solar radiation. Minimum energy fixation (0.05 per cent) occurs in grassland under limited water available in semi-arid zone and the maximum in dry sub-humid zone (0.5 per cent) of total incident solar radiation. Out of total energy fixed 11.20 Kcal/m^2/day and 6.87 Kcal/m^2/day is accumulated in the aboveground parts and 2.95 Kcal/m^2/day and 4.52 Kcal/m^2/day is transferred to underground system in protected and grazed grasslands, respectively. SINGH et al. (1977) have reported that out of total energy fixed, 6.48 Kcal/m^2/day is accumulated in the aboveground parts and 5.89 Kcal/m^2/day is transferred to underground system of a tropical grassland. DWIVEDI (1970) has determined that in the *Dichanthium* grassland at Varanasi, about 30 per cent of gross energy fixed is accumulated for plant respiration. BILLORE et al. (1975) have compared the respiratory loss between *Tectona grandis* community and *Cymbopogon martinii* community, they found that the respiratory loss was 77 per cent and 23 per cent of gross production respectively.

The transfer of energy from standing live compartment to standing dead compartment occurs at the rate of 4.98 Kcal/m^2/day and 0.99 Kcal/m^2/day amounting to 44.48 per cent and 14.35 per cent of annual net aboveground production in protected and grazed grasslands, respectively. Nearly 19.3 per cent and 28.1 per cent of the total transferred to standing dead compartment find its way into the litter compartment in protected and grazed grasslands, respectively. The rate of litter and underground disappearance were 1.04 Kcal/m^2/day and 2.90 Kcal/m^2/day in protected, 0.33 Kcal/m^2/day and 4.09 Kcal/m^2/day in grazed grasslands. This shows that some surplus energy is carried over in the aboveground parts which may be an indication of the herbage available for grazing, harvesting and also of a high P/R ratio which is a characteristic of seral communities.

During present study, the annual energy conserving efficiency of *Dichanthium* dominated grasslands was found 0.805 per cent on protected and 0.626 per cent on grazed grasslands. Thus it shows that energy conserving efficiency of protected grassland is higher as compared to grazed grassland which may be due to higher annual net production on protected as compared to grazed grasslands. SINGH & JOSHI (1977) have calculated the efficiency of energy capture for thirteen grasslands in India. The values ranged from 0.23 per cent (growing season) for the semi-arid grassland at Pilani to 1.66 per cent for dry humid grassland at Kurukshetra. The annual energy conserving efficiency of tropical grasslands ranges from as low as 0.13 per cent at Pilani (KUMAR & JOSHI, 1972). PANDEYA & al. (1974) have calculated the energy conserving efficiency of twelve localities around Rajkot of western India and have got results in between 0.42 per cent and 4.0 per cent. SINGH (1972) has reported 3.24 per cent in *Heteropogon contortus* grassland in protected and 0.69 per cent in grazed conditions in Chakia forest. PANDEY (1977) has reported the energy conserving efficiency of *Aristida* type grassland, 1.5 per cent on protected and 1.26 per cent on grazed grasslands of Chakia forest. In tropical grassland there is a fluctuation in the energy conserving efficiency which may be due to fluctuation in solar radiation receiving at different places. NAIK (1973) has reported that the value of energy conserving efficiency is too low because of too high solar radiation taken up for the calculation.

The efficiency of energy capture will depend upon not only the water use efficiency and soil moisture status but also on the other driving and abiotic variables, as also on the caloric values of the plant material. Further, apart from dynamic layer, structure of the canopy which is also congenial to light utilization governs the energy fixation. Majority of plants in tropical environment are C_4 having higher water use efficiency, higher range of optimum temperature for photosynthesis and no photorespiration. During present study the temperature was never too low so it did not become a limiting factor for growth as it happens in the temperate climate. Thus most of the tropical grasslands are more efficient in energy capture as compared to temperate grassland. Solar radiation is greater in tropical environment ranging from 1.5 to 2.0 x 10^6 Kcal/m^2/year. Thus a combination of greater solar radiation, unique physiological characteristic of C_4 plants, occurrence of year long growth and a dynamic multi-layered canopy results in higher net production and hence higher energy conserving efficiency.

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REFERENCES

BILLORE, S.K., MALL, L.P. and DAWAR, K., 1975. Ecology of respiratory loss in teak and *Cymbopogon* grass with reference to deciduous forest and grassland. *Proc. Indian Nat. Sc. Acad.*, 41 B, 169-171.

DAUBENMIRE, R.F., 1959. *Plant and Environment*. New York. John Wiley and Sons, Inc.

DWIVEDI, R.S., 1970. A comparative study of energetics and cycling of phosphorus uptake 32_P in wheat (*T. aestivum L.*) and Marval grass (*D. annulatum* Stapf.). Ph. D. thesis, Banaras Hindu Univ., Varanasi, India.

KUMAR, A. and JOSHI, M.C., 1972. The effect of grazing on the structure and productivity of vegetation near Pilani, Rajasthan, India. *J. Ecol.*, 60, 665-675.

LIETH, H., 1968. The measurement of calorific values of biological material and determination of ecological efficiency. In F.E. Echardt (eds.). *Functioning of terrestrial ecosystems at the primary production level*, UNESCO, Paris, 233-292.

LINDEMAN, R.L., 1942. The trophic dynamic aspect of ecology. *Ecol.*, 23, 399-418.

NAIK, M.L., 1973. Ecological studies on some grasslands of Ambikapur : with special reference to their structure and productivity, Ph. D. thesis, Saugar University, Sagar, India.

NICHIPOROVICH, A.A., 1967. Aims of research on photosynthesis of plant as factor in productivity. Photosynthesis of productive system.

PANDEYA, S.C., MANKAD, M.R. and JAIN, H.K., 1974. Potentialities of net primary production of arid and semi-arid grazing lands of India. *Proc. XII Int. Grassland Congress.* 136-170.

PANDEY, T.N., 1977. Measurement of rate of primary production in a Varanasi grassland. Ph. D. thesis, Banaras Hindu University, Varanasi, India.

SINGH, J.S. and JOSHI, M.C., 1977. Primary production. In R.T. Coupland (ed.) *Grassland ecosystem of world : their analysis and uses.* Cambridge University Press.

SINGH, J.S., SINGH, K.P. and YADAVA, P.S., 1977. Static, compartment model of energy flow and nutrient cycling. In R.T. Coupland (ed.). *Grassland ecosystems of the world : their analysis and uses.* Cambridge University Press.

SINGH, J.S. and YADAVA, P.S., 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland at Kurukshetra, *India Ecol. Monograph*, 44, 351-375.

SINGH, U.N., 1972. Phytosociology and productivity of grazed and ungrazed grasslands of Chakia forest, Varanasi, Ph. D. thesis, Banaras Hindu University, Varanasi, India.

TERRIEN, J., TRUFFAUT, G. and CARLES, J., 1957. *Light vegetation and chlorophyll.* Philosoph. Libr., New York.