Vegetatio 74: 47–53, 1988

Vegetation, biomass and productivity of seral grasslands of Cherrapunji in north-east India

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accepted 21.10.1987

Keywords: Desertification, Grassland, Succession: arrested, Tropics: humid

Abstract

This study deals with the composition of vegetation, biomass and productivity of four different grassland types at Cherrapunji, India. Varied levels of degradation of the climax mexed evergreen forest are represented by these grasslands. Where the soil profile is deep, the grasslands are maintained through frequent fire. At each site, belowground production is more than double aboveground production. Annual turnover rates for the belowground biomass in these grasslands are more dynamical than their temperature counterparts. These grasslands are maintained under high stress conditions of thin soil cover, highly leached nutrient-deficient soils, frequent fires, and low soil moisture retention in spite of a high annual rainfall of 10372 mm.

Nomenclature follows: Hooker (1875–97); for grasses; Dabadghao of Shankarnarayanan (1973).

Introduction

The biomass and productivity of grassland ecosystem types of the world particularly from temperate regions have received much attention (Murphy 1975; Numata 1979; Wielgolaski *et al.* 1981). The savanna grasslands of India are less known and much of the available information is based on monsoon grasslands with a rainfall < 1000 mm. Information on savanna grasslands developed in the humid tropics is meagre. The study done at Cherrapunji, India, is particularly interesting because this is the first report, as far as we know, on grasslands developed under an annual rainfall of over 10000 mm. The climax rainforests represented by protected sacred groves in the area (Boojh & Ramakrishnan 1983; Ramakrishnan 1984; Khiewtan 1986) are extremely fragile and disturbance leads to different types of savanna grasslands. With a very high rainfall, one would normally expect high biomass productivity values for the aboveground component to the belowground parts. However, the grasslands described here exist because of fire or soil induced drought. Therefore, an understanding of the biomass and productivity dynamics of these grasslands of the humid tropics is significant.

The climate

The climate at Cherrapunji (25°15′N, 91°45′E and 1313 m elevation) located 50 km south of Shillong is typically monsoonic with an annual average rainfall of 10372 mm (mean for 1973–1983), about 96% of which occurs between April to October. The mean monthly maximum and minimum temperatures during the summer are 24 °C and 14 °C, respectively. Indeed this area is considered to be one of the wettest places of the world where annual rainfall may be > 24500 mm. November to February are winter months of which February is relatively dry. Mean monthly maximum and minimum temperatures for the winter period are 17 °C and 6 °C, respectively. The dry summer lasts only one transitional month (March) between the winter and rainy seasons, with mean monthly maximum and minimum temperatures of 20 °C and 12 °C, respectively.

Methods

Site characteristics and phytosociology

Four grassland study sites of 2 to 3.5 ha (three replicates of each site) were selected at Cherrapunji. All sites were south facing slopes of 35° to 45°. These include: 1. *Osbeckia* type on slopes with a mean soil depth of about 40 cm, the vegetation of which was last burnt 6 years prior to the initiation of this study, 2. *Arundinella* type on slopes under similar conditions as *Osbeckia* type but where an additional burning of the grassland was done in March, one month before the study period, 3. *Ischaemum* type on slopes with similar soil conditions as above but subjected to 2-yearly burns at regular intervals; the last burning being done in March one month before the study period and 4. *Eragrostiella* type on highly degraded slopes which had a gravelly, partially weathered mineral soil with a maximum depth of 30 mc and with scattered stunted grasses.

Vegetation analysis at each replicate site was based on 30 randomly located 1 m^2 quadrats to estimate frequency, density and basal area for all species. Importance values, the sum of relative frequency, relative density and relative dominance (Curtis 1959) were calculated for each species.

Soil analysis

Soil sampling at all sites was done in July. Under *Arundinella* and *Ischaemum* types, soil sampling was done in the same year and the year following the burn. Soil samples were air dried, ground and passed through a 0.2 mm sieve. Soil pH was determined in a 1:5 soil-water suspension. Total Kjeldahl nitrogen, carbon (Walkely-Black method), NO_3-N, PO_4-P and cations were analysed following Allen *et al.* (1974). Magnesium and calcium were analysed by EDTA titration, while potassium was estimated by flame emission. NO_3-N was estimated by the phenol-di-sulphonic acid method and PO_4-P was estimated by the molybdenum blue method, both colorimetrically.

Biomass and productivity

Above and belowground biomass measurements done at monthly intervals are based on 10 harvests from 1 m^2 quadrats, at each replicate site. Aboveground biomass was divided into living, standing dead and litter, and separately considered for major species. Belowground biomass was harvested by excavating blocks of soil (10 replicates at each site) 30 cm deep using a 10 cm diam. soil core. The soil block was divided into three units at 10 cm intervals (0 – 10, 10 – 20 and 20 – 30 cm) for measuring root distribution. Both aboveground and belowground parts were washed and rinsed with distilled water, dried at 80 °C for 24 h and weighed. Aboveground net primary productivity was calculated by including dead material disappearing during monthly intervals following the method of Wiegert & Evans (1964). Belowground net primary production was estimated by summation of the positive increments of root biomass alone (Dahlman & Kucera 1965).

Turnover of biomass was calculated using the formula:

$$\text{Turnover} = \frac{\text{ANP} + \text{BNP}}{\text{Maximum biomass}} \quad (1)$$

where, ANP = Aboveground net primary production, BNP = Belowground net primary production.

Turnover time was calculated by reversing the turnover. Statistic analysis using one-way ANOVA was done to detect differences between grassland types.

Results

These grassland soils are generally acidic, highly leached and nutrient poor. The pH values ranged from 5.2 in the *Eragrostiella* type to 5.8 in the *Arundinella* type, moisture content varied from 14 to 17%, organic carbon from 1.4 to 2.0%, K from 0.10 to 0.20 meq/100 g, Ca from 0.67 to 1.30 and Mg from 1.60 to 2.90 meq/100 g. Nitrate and phosphorus were lowest in the *Eragrostiella* type, with values 0.10 and 0.08 mg/100 g. Soil pH and nutrient levels were significantly lowest for the *Eragrostiella* type ($P < 0.05$), and cations were higher in the *Arundinella* type. In the year of the burn, soil pH increased and then declined ($P < 0.05$) subsequently. The nitrogen content in the soil declined soon after the burn ($P < 0.05$). The cations generally improved after the burn ($P < 0.05$). The floristic structure of the four types distinguished is presented in Table 1. Grasses predominate in each of the types. Only six forbs occur regularly, and one shrub *Osbeckia crinita.* Tree saplings of four species were found, but only in the *Osbeckia* type.

Many species were shared between the *Osbeckia* and the *Arundinella* types. After the burn, some species such as *Gentiana quadrifaria* and *Ischaemum goeblii* appeared, others e.g. *Phyllanthus simplex* increased in number, while others such as the shrub *Osbeckia crinita* declined. Species composition of the *Ischaemum* type is similar to that in the *Arundinella* type, except for increases in *Ischaemum goeblii, Fimbristylis complanata* and *Osbeckia capitata.* These species are also in common with the *Eragrostiella* type.

In the *Osbeckia* type, perennial species constituted about 58% of the species in the community. Annuals were more important in the burnt sites, contributing 60% of the species in the *Ischaemum* type, and even more on desertified land (*Eragrostilla* type).

Perennials contributed 71 – 83% to the total living biomass in these grasslands (Table 2a). Biomass increased slightly during the second year after burning. Soon after the burn, standing dead and litter declined drastically, but recovered rapidly the subsequent year.

Peak aboveground living biomass occurred in September, whereas standing dead peaked in December. Lowest values for living aboveground biomass were found in January and for standing dead in April. Litter production was maximal in March and minimal in August. See Fig. 2.

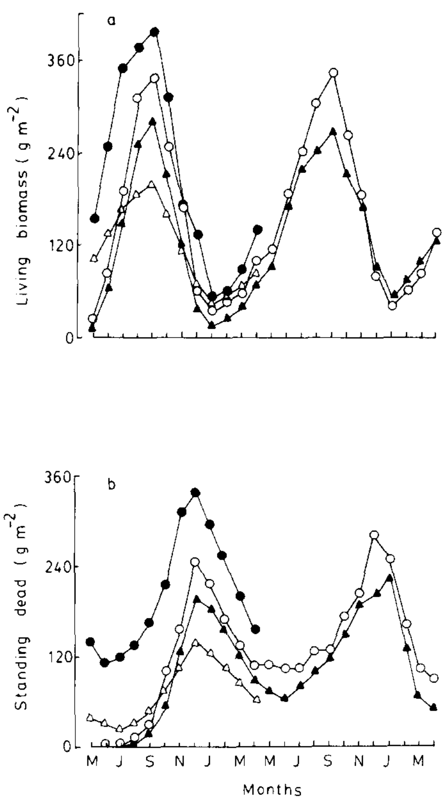
More than 70% belowground biomass was located in the top 0 – 10 cm of soil (Table 2b). Under the *Ischaemum* type about 81% of the root biomass was present in this zone. The *Eragrostiella* type had significantly lower (P < 0.05) belowground biomass compared to the other types. Belowground biomass

Table 1. Importance value indices (IVI) of species of grasslands at Cherrapunji in north-eastern India. Species occurring only with values <5% are omitted. Full data are available on request. * = Osbeckia type, A = Arundinella type, I = Ischaemum type, E = Eragrostiella type.

Total number of species	O	A	I	E
Grasses and other monocots	29	21	29	24
Arundinella bengalensis	24.6	32.8	14.6	21.1
Arundinella khaseana	-	11.2	8.3	3.6
Arundinella nepalensis	13.4	2.3	5.4	-
Axonopus compressus	-	-	5.4	-
Capilipium assimale	2.3	-	5.4	-
Carex cruciata	21.3	14.5	6.5	4.4
Chrysopogon gryllus	24.0	20.3	8.2	21.1
Dimeria fuscescens	-	-	12.1	17.1
Eragrostiella leioptera	-	-	12.7	40.2
Eulalia trispicata	6.4	21.2	9.6	-
Eulalia quadrinervis	10.0	15.1	-	-
Fimbristylis complanata	-	11.1	38.5	26.6
Fimbristylis thomsonii	20.1	-	18.1	2.9
Heteropogon contertus	5.2	-	-	-
Ischaemum goeblii	-	19.1	52.3	21.9
Paspalum arbiculare	10.5	25.8	1.8	10.8
Setaria glauca	14.0	19.9	5.6	-
Forbs				
Anotis oxyphylla	-	-	-	5.3
Borreria articularis	-	-	-	29.5
Gentiana quadrifaria	-	20.9	24.0	13.2
Leucus ciliata	5.7	-	-	-
Osbeckia capitata	10.2	9.6	20.8	18.0
Phyllanthus simplex	11.9	24.3	11.5	13.6
Plectoranthus japonicus	16.3	3.7	3.1	-
Pogostemon quricularis	3.1	10.0	10.7	2.4
Shrubs				
Melastoma malabathricum	1.1	6.0	-	-
Osbeckia crinita	51.5	19.9	4.7	23.0

Table 2. (a) Contribution of aboveground biomass by different plant groups (b), belowground biomass (g m^{-2} ± SE) and (c) primary productivity (g m^{-2} yr^{-1}) in grasslands at Cherrapunji in north-eastern India.

	Osbeckia type	*Arundinella* type		*Ischaemum* type		*Eragrostiella* type
	1983	1983	1984	1983	1984	1983
(a) *Aboveground biomass*						
Perennials living	334 ± 25.7	261 ± 21.8	266 ± 23.5	205 ± 18.5	231 ± 18.0	146 ± 12.4
Annuals living	67 ± 4.9	79 ± 6.1	79 ± 6.4	76 ± 5.9	82 ± 6.8	60 ± 4.6
Total living	401 ± 18.4	340 ± 24.2	335 ± 27.9	281 ± 7.2	313 ± 23.9	206 ± 11.8
Standing dead	169 ± 15.0	28 ± 1.9	129 ± 6.8	21 ± 0.7	118 ± 6.1	49 ± 4.5
Litter	72 ± 4.8	5 ± 0.3	49 ± 3.2	4 ± 0.2	65 ± 3.0	33 ± 3.0
Total biomass	641 ± 29.2	372 ± 26.5	523 ± 30.2	306 ± 23.3	495 ± 31.2	281 ± 24.2
(b) *Belowground biomass*						
Soil 0 – 10 cm	820 ± 65.2	773 ± 47.4	780 ± 49.4	797 ± 62.7	811 ± 54.3	555 ± 39.0
10 – 20 cm	159 ± 10.2	172 ± 13.0	182 ± 9.6	114 ± 7.7	117 ± 7.0	130 ± 6.3
20 – 30 cm	109 ± 8.3	111 ± 8.6	115 ± 6.2	76 ± 4.7	78 ± 5.0	49 ± 2.8
Soil Total	1088 ± 81.4	1057 ± 41.6	1077 ± 75.2	986 ± 71.0	1007 ± 71.5	734 ± 26.6
(c) *Primary productivity*						
Aboveground	579	420	569	357	485	346
Belowground	990	986	997	932	950	631
Total	1569	1406	1566	1289	1435	977



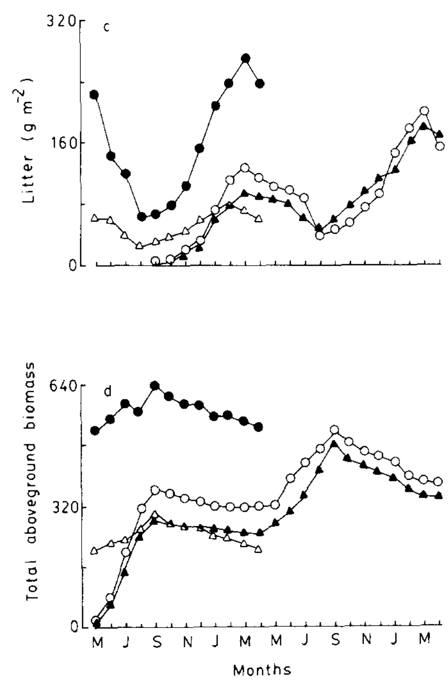


Fig. 1. Monthly changes of aboveground living biomass (a), standing dead (b), litter (c) and total aboveground biomass (d). *Osbeckia* type (●), *Arundinella* type (○), *Ischaemum* type (▲) and *Eragrostiella* type (△).

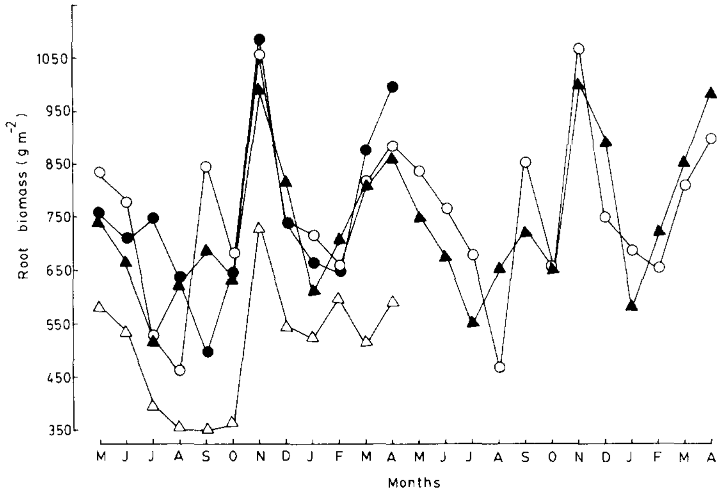


Fig. 2. Monthly changes in total belowground biomass (gm^{-2}) *Osbeckia* type (●), *Arundinella* type (○), *Ischaemum* type (▲) and *Eragrostiella* type (△).

fluctuated considerably ($P<0.05$) during the year (Fig. 2); maximum values were attained in November.

The *Ischaemum* type generally had a lower primary productivity than the *Osbeckia* and *Arundinella* types (Table 2b). The *Eragrostiella* type had the lowest productivity. For the *Ischaemum* and *Arundinella* types, aboveground productivity declined after burning ($P<0.05$) but recovered in the following year. This was also reflected in the total productivity of the system. Belowground primary productivity however, did not change much.

Discussion

The grasslands at Cherrapunji represent varied levels of site degradation, and are arrested seral communities in common with the rest of the Indian subcontinent. At Cherrapunji, the climax is represented by sacred groves occurring as a relict vegetation (Ramakrishnan *et al.* 1981). Clear-cutting of the forest for slash and burn agriculture in the past has contributed to grassland formation in this high rainfall area. After clear-cutting of the forest, natural recovery processes on steep slopes are retarded because of rapid wash-out of the top soil and nutrients, so that these grasslands are often maintained in an arrested state. However, the *Osbeckia* type on deeper soils are often maintained by frequent fire. The *Arundinella* type is derived from burning the *Osbeckia* type and would revert to the latter in the following year in the absence of fire. Regular burning at 2-year intervals results in the development of the *Ischaemum* type grassland. On slopes where the soil is very thin, the grasslands remain in an arrested stage even without fire.

A comparative study of the *Arundinella* type subjected to a recent burn and that undisturbed for the past six years (*Osbeckia* type) suggests that seeds of trees and shrubs are available in the neighbourhood, and could lead to the establishment of trees under favourable conditions. While in the *Osbeckia* type perennial species dominate annuals are more conspicuous after burning in the *Arundinella* type, and even more in the *Ischaemum* type. It seems reasonable to conclude that fire may cause an increase in annuals on these grasslands (Reynold & Bohning 1956; Daubenmire 1968) and from dicot species to grasses (Humphrey 1958; Sharrow & Wright 1977).

Soil fertility may also contribute to the shift from perennials to annuals. This trend was evident on the desertified *Eragrostiella* type. However, the success of perennial species such as *Arundinella bengalensis, Chrysopogon gryllus* and *Carex cruciata* in infertile soils is because of well developed rhizomes that help in regeneration after the burn.

The decline in aboveground biomass after burn-

Table 3. Net primary productivity (g m^{-2}) and rainfall of some monsoon grasslands.

Site	Grassland type	Aboveground	Belowground	Total	Rainfall	Author
Kurukshetra (India)	Mixed grass	2407	1131	3538	790	Singh & Yadava (1974)
Varanasi (India)	*Desmostachya* (Upland)	2218	1377	3595	843	Singh (1972)
Jhansi (India)	Sehima – *Heteropogon*	1019	497	1516	936	Shanker *et al.* (1973)
Calabozo (Venezuela)	*Trachypogon* dominated	492	190	682	1355	San Jose & Medina (1976)
Present study (Cherrapunji)	Mixed grass – *Osbeckia* type	579	990	1569	10372	
	Mixed grass – *Arundinella* type	420	986	1406	10372	
	Mixed grass – *Ischaemum* type	357	932	1289	10372	
	Mixed grass – *Eragrostiella* type	346	631	977	10372	

ing has been observed by others (Smith 1960; San Jose & Medina 1976). The decline in aboveground biomass is accompanied by a decline in aboveground productivity. Recovery to pre-burn levels occurs the following year. This pattern contrasts with those reported in many studies (Kucera & Ehrenreich 1962; Hadley & Kieckhefer 1963; Pandey 1974), where biomass and productivity in the first year after burning exceeded that of unburnt control plots. A time lag in the recovery of biomass and productivity to the original level after the burn, as noted here was also observed by Cook (1939), Smith (1960) and Mott (1982). Extreme climatic conditions with heavy losses of nutrients through water erosion (Ramakrishnan & Toky 1981; Mishra & Ramakrishnan 1983) could be responsible for this time lag in recovery.

Total net primary productivity during the present study, generally was lower than values reported by others under a monsoonic climate except for one report from Jhansi, India and another from Calabozo, Venezuela, where the values are comparable or somewhat lower (Table 3). However, the more interesting point that emerges is the relative productivity of aboveground versus belowground parts. In most studies, belowground productivity is reported to be almost half that of aboveground productivity; the reverse is true at Cherrapunji. Higher productivity of belowground parts may partly be due to low soil fertility for efficient uptake of nutrients from the soil (Nye & Tinker 1977) and partly because of drought conditions (Struik & Bray 1970) due to poor soil moisture retention in spite of high rainfall.

The annual turnover of biomass of the belowground parts of about 1.0 is comparable to that of aboveground parts and agrees with data for another monsoon grassland in Kurukshetra, India (Singh & Yadava 1974). This suggests that belowground and aboveground biomass have a very high turnover rate tropical grassland. This pattern differs from that in temperate grasslands where the reported annual turnover values are often much lower, ranging from 0.19 to 0.69 (Sims & Singh 1978).

In conclusion: the grasslands at Cherrapunji are seral in nature, and they are developed and maintained under high stress conditons. Highly eroded and leached nutrient-deficient soils, frequent fires, and soil induced drought despite heavy rainfall, are some of the special features of the environment in which these grasslands are supported.

Acknowledgements

This work was done at the Centre for Eco-Development, North-Eastern Hill University and supported by a research grant from the University Grants Commission, New Delhi. We thank Dr P. Sudhakar Swamy for help in the preparation of this paper.

References

Allen, S. E., Grimshaw, H. M., Parkinson, J. A. & Quarnby, C. 1974. Chemical analysis of ecological material. Blackwell Scientific Publ., Oxford, England.

Boojh, R. & Ramakrishnan, P. S. 1983. Sacred groves and their role in environmental conservation. In: Strategies for environmental management. Souvenir. Vol. pp. 6–8. Dept. Sci. Environ., U.P. Govt. Lucknow.

Cook, L. 1939. A contribution to our information on grass burning. South Afr. J. Sci. 36: 270–282.

Curtis, J. T. 1959. The vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin Press, Wisconsin.

Dabadghao, P. M. & Shankarnarayanan, K. A. 1973. The grass cover of India. Indian Council of Agricultural Research, New Delhi.

Dahlman, R. G. & Kucera, C. L. 1965. Root productivity and turnover in native prairie. Ecology. 46: 84–89.

Daubenmire, R. 1968. Ecology of fire in grasslands. Adv. Ecol. Res. 5: 209–266.

Hadley, E. B. & Kieckhefer, B. J. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44: 389–395.

Hooker, J. D. *et al.* 1875–1897. The flora of British India. L. Breeve & Co., London.

Humphrey, R. R. 1958. The desert grassland, a history of vegetational change and an analysis of causes. Bot. Rev. 24: 193–252.

Khiewtan, R. S. 1986. Ecosystem function of protected forests of Cherrapunji and adjoining areas. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Kucera, C. L. & Ehrenreich, J. H. 1962. Some effect of annual burning on central Missouri Prairie. Ecology 43: 334–336.

Mishra, B. K. & Ramakrishnan, P. S. 1983. Slash and burn agriculture at higher elevation in north-eastern India. I. Sediment, water and nutrient losses. Agric. Ecosystem Environ. 9: 69–82.

Mott, J. J. 1982. Fire and survival of *Stylosanthes* spp. in dry savanna woodlands of northern territory. Aust. J. Agric. Res. 33: 203–211.

Murphy, P. G. 1975. Net primary productivity in tropical terrestrial ecosystems. In: Lieth, H. Whittaker, R. H., (eds), Primary productivity of the biosphere, pp. 212–231. Springer, New York.

Numata, M. 1979. Ecology of grasslands and bamboo lands of the world. Springer, Berlin.

Nye, P. H. & Tinker, P. B. 1977. Solute movement in the soil root system. California University Press, Berkeley.

Pandey, A. N. 1974. Short term effect of burning on the aboveground production of *Dichanthium annulatum* grassland stands at Varanasi. Trop. Ecol. 15: 152–153.

Ramakrishnan, P. S. 1984. Conservation of rainforest in north-eastern India. In: Valdiya, K. S. & Singh, J. S. (eds), Environmental regeneration in the Himalaya: Concepts and strategies, pp. 69–84.

Ramakrishnan, P. S. & Toky, O. P. 1981. Soil nutrient status of hill agro-ecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India. Plant Soil 60: 41–64.

Ramakrishnan, P. S., Toky, O. P., Mishra, B. K. & Saxena, K. G. 1981. Slash and burn agriculture in north-eastern India. In: Mooney, H. A., Bonnicksen, T. M., Christensen, N. L., Lotan, J. E. & Reiners, W. A. (eds), Fire regimes and ecosystem properties, pp. 570–586. U.S.D.A., Forest Service Tech. Report W.O. 26. Honolulu. Hawaii.

Reynold, G. H. & Bohning, J. W. 1956. Effect of burning on a desert grass-shrub range in southern Arizona. Ecology 13: 393–401.

San Jose, J. J. & Medina, Y. E. 1976. Organic matter production in the *Trachypogon* savanna at Calabozo, Venezuela. Trop. Ecol. 17: 113–124.

Shankar, V., Shankarnarayan, K. A. & Rai, P. 1973. Primary productivity, energetics and nutrient cycling in *Sehima-Heteropogon* grasslands. I. Seasonal variation in composition, standing crop and net production. Trop. Ecol. 14: 238–251.

Sharrow, S. H. & Wright, H. A. 1977. Effect of fire, ash and litter on soil nitrate, temperature, moisture and Tobosa grass production in the rolling plains. J. Rang Mgmt. 30: 266–270.

Sims, P. L. & Singh, J. S. 1978. The structure and function of ten western North American grasslands. III. Net primary production, turnover and efficiencies of energy capture and water use. J. Ecol. 66: 573–597.

Singh, J. S., Singh, K. P. & Yadava, P. S. 1979. Ecosystem synthesis. In: Coupland, R. T. (ed.), Grassland ecosystems of the world; analysis of grassland and their uses. Cambridge University Press.

Singh, J. S. & Yadava, P. S. 1974. Seasonal variation and net primary productivity of a tropical grassland at Kurukshetra, India. Ecol. Monogr. 44: 351–376.

Smith, E. L. 1960. Effects of burning and clipping at various times during the wet season on tropical tall grass range in northern Australia. J. Range Mgmt. 13: 197–203.

Struik, G. J. & Bray, J. R. 1970. Root-shoot ratios of native forest herbs and *Zea mays* at different soil-moisture levels. Ecology 5: 892–893.

Toky, O. P. & Ramakrishnan, P. S. 1983. Forest wealth of north-eastern India and its conservation. In: Paliwal, G. S. (ed.), The vegetational wealth of Himalayas. Puji Publishers, Vaishali, New Delhi.

Wiegert, R. G. & Evans, F. C. 1964. Primary production and the disappearance of dead vegetation on an old field in south eastern Michigan. Ecology 45: 1–45.

Wielgolaski, F. E., Bliss, L. C., Svoboda, J. & Doyle, G. 1981. Primary production of tundra. In: Bliss, L. C., Heal, O. W. & Moore, J. J. (eds), Tundra ecosystem: a comparative analysis, pp. 187–226. Cambridge University Press, Cambridge.