Dry matter production and transfer dynamics in a humid grassland of Western Ghats in southern India

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Abstract

Monthly changes in plant biomass, net primary productivity and transfer dynamics of tropical grassland in the Western Ghats region of southern India were measured. The maximum above-ground live shoot biomass was observed in November 1985 (545 g/m^2) and maximum below-ground biomass in February 1985 (160 g/m^2). Total annual net primary production is estimated to be 1456 g/m^2. Of the total input of 3.39 $g/m^2/d$ into the system, about 83% was channelled to above-ground and 17% to below-ground. The total disappearance was 0.79 $g/m^2/d$ which was 22.3% of the total input. There is a net surplus of organic material as the rate of disappearance is slower than the rate of accumulation of dry matter. Thus, the grassland showed a net accumulation of surplus organic matter, indicating the seral nature of this grassland.

Introduction

Grasslands occupy 39.8 per cent (12.12 million ha) of the total reporting area of the Indian sub-continent (Singh 1987). In Tamilnadu the grasslands in the Western Ghats region have emerged from excessive cutting and felling of forests. The grasslands occur on almost all soil types and their distribution is predominantly governed by climatic factors, related chiefly to latitudinal influences (Whyte 1968).

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Biotic influences on structural and functional attributes of grasslands depend on the type of vegetation, rainfall and intensity of grazing. Mild grazing keeps the herbaceous layer more diverse and productive, compared to overgrazed and ungrazed situations (Singh *et al.* 1985; Karunaichamy and Paliwal 1989).

Most work on grassland ecosystems in this country has been located in western (Pandeya *et al.* 1977), northern (Singh and Yadava 1974; Sinha *et al.* 1991), north-eastern (Ramakrishnan and Ram 1988) and eastern (Mishra and Mishra 1984) India, and has been concerned exclusively with higher altitude regions of the Himalayas (Ram *et al.* 1989). Virtually no information is available on the Western Ghats grassland ecosystems in the southern part of this country. Hence the present study deals with the biomass, net primary production and system transfer functions of the humid grasslands in the Western Ghats region of southern India dominated by *Pennisetum polystachyum* Schult. and *Eupatorium odoratum*, Linn.

Materials and methods

Study area:

The study area is located in the Kanniyakumari District of Tamilnadu, south India (8° 17′N, 77° 20′E) at an elevation of 276 m above mean sea level. This area was open grazing lands, grazed occasionally by sheep and cattle. The annual rainfall was 1496 mm, with the maximum rainfall in June and the minimum in March (Figure 1). The mean maximum and minimum temperatures recorded during the study period (January–December 1985) were 32.2 °C and 22.5 °C, respectively.

The soils of the area are sandy clay loams. Water holding capacity of the soil was estimated to be 42.7%. The soil is slightly alkaline (pH 7.9). Soil nutrient levels were organic carbon (1.41%), nitrogen (0.45%), phosphorus (0.04%),

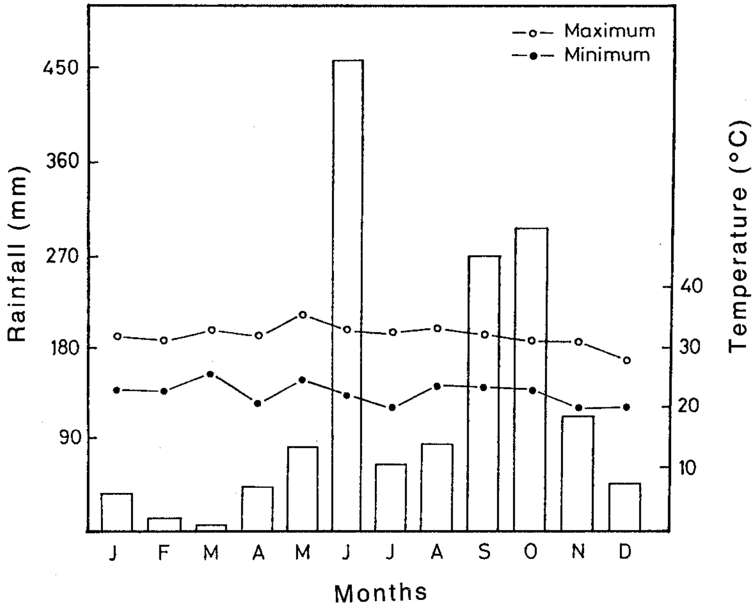

Figure 1. Monthly precipitation plus mean minimum and maximum temperatures during the study period in a humid grassland of Western Ghats in southern India.

potassium (0.18%), calcium (0.02%) and magnesium (0.43%).

Phytosociology

Three replicates of 2–5 ha of grassland ecosystem were selected. Vegetational analysis was based on 1 m^2 quadrats laid randomly. Frequency, density and basal area were recorded for all species. Importance value index (IVI) which is an integrated measure of the relative frequency, relative density and relative dominance (Curtis 1959) was also estimated.

Biomass and productivity

Biomass was estimated by the harvest method (Milner and Hughes 1968). The optimum quadrat size (50 × 50 cm) was obtained through the species area curve method (Goodall 1952). Ten quadrats were sampled randomly at monthly intervals. Harvested samples were separated into live shoots and dead shoots and ground litter was collected separately. The below-ground biomass was sampled by a sub-sampling (25 × 25 × 30 cm) within the harvested plot. The root mass was separated by washing thoroughly under running water using 2 mm mesh screens. All plant samples collected were oven dried at 80 °C till a constant weight was obtained.

The above-ground net primary production (ANP) was calculated by the sum of positive changes in above-ground biomass plus mortality (Singh and Yadava 1974). The below-ground net primary production (BNP) was calculated by summation of positive increments of below-ground biomass.

Net accumulation and disappearance rates of dry matter were calculated by the methods of Singh and Yadava (1974), and Sims and Singh (1978b).

(i) Transfer of live shoot to dead shoot was calculated by the summation of the positive changes in the dead shoots on successive sampling dates.

(ii) Transfer of dead shoot to litter (L) was calculated by the summation of negative changes in the dead shoots.

(iii) Disappearance of litter (LD)
LD = (L) + (Initial litter biomass) − (Final litter biomass)

(iv) Disappearance of below-ground biomass (BD)
BD = (Initial below-ground biomass) + (BNP) − (Final below-ground biomass)
(v) Total disappearance (TD)
TD = (LD) + (BD)

Turnover rates for above-ground and below-ground biomass were calculated by the method of Dahlman and Kucera (1965). Turnover time was calculated by reversing the turnover.

Result

The most important species in the pasture (based on the importance value index, IVI) was *Pennisetum polystachyum* (IVI = 225.6), followed by *Eupatorium odoratum* (42.3), *Heliteres isora* (17.0) and *Desmodium gangeticum* (15.0).

Monthly changes in live shoots, dead shoots, litter and below-ground are depicted in Figure 2. Monthly biomass changes in live shoots and below-ground parts also showed a bimodal pattern.

Shoot biomass

The live shoot biomass ranged between 35–545 g/m^2 during the study period (Figure 2). It increased gradually from January to a peak in June, declined steadily until October, then rose sharply to a second peak in November.

Live shoot biomass was related to plant height and density of vegetation in a linear fashion, according to the following equation:

$$Y = -104.10 + 0.78 X_1 + 1.65 X_2$$

where Y is the live shoot biomass (g/m^2), X_1 is the density of vegetation (tillers/m^2) and X_2 is the plant height (cm). This relationship explains 88.4% of the variation in live shoot biomass ($r = 0.94$, $P < 0.001$).

Dead shoots (SD)

A substantial amount (112 − 301 g/m^2) of dead shoot biomass was recorded throughout the study period (Figure 2). The pattern was similar to that for live shoots with peaks in July and November–December, although a third peak occurred in March.

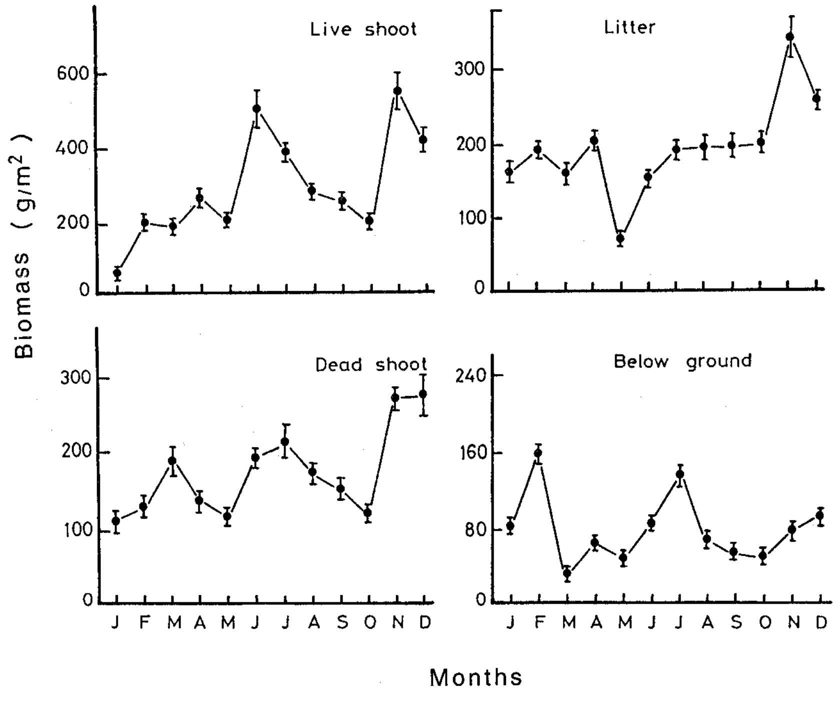

Figure 2. Monthly variations in biomass of various compartments in a humid grassland of Western Ghats in southern India. Vertical bars represent ± SD.

Litter (L)

Litter biomass ranged from 75–347 g/m^2 during the study period (Figure 2). For much of the time, litter biomass was relatively stable around 200 g/m^2 but there was a sharp drop in May and a sharp increase in November.

Below-ground biomass

The below-ground biomass ranged from 31–160 g/m^2 (Figure 2), with peaks occurring in February and July.

Above-ground net primary production (ANP)

The above-ground net primary production was 1212 g/m^2. The peak community biomass was 1020 g/m^2. Thus, the estimate of net production obtained from the sum of species peaks was greater than peak community biomass by 16% during the study period.

Below-ground net primary production (BNP)

The total net below-ground primary production was found to be 247 g/m^2 and the total net primary production (TNP) was 1456 g/m^2.

Turnover rate

The turnover rate and time were observed to be 1.49 g/m^2 and 0.67 years for canopy and 1.53 g/m^2 and 0.65 years for below-ground biomass.

Discussion

In the present study, maximum live shoot biomass occurred during the rainy season, whereas minimum live shoot biomass occurred in January. This pattern is similar to that reported by Singh and Ambasht (1975). The grasses showed most growth after June and October rains. The higher above-ground biomass of this study area could be a function of the species, *Pennisetum polystachyum*, which dominated the community, and had a growth rate of 11.4 g/m^2/d. A further contributing factor could be the moderate grazing and clipping which generally contribute to increases in above-ground biomass. The increased tiller production would also have increased the above-ground biomass as reported by others (Coupland 1979; Stout and Brooke 1985).

The values for dead shoot biomass reported here are lower than those reported from other dry and humid regions of Kurukshetra and Sagar (Singh and Joshi 1979). However, dead shoot production is always lower in humid than in arid and semi-arid regions (Sims and Coupland 1979). Dead shoot biomass was related to temperature and rainfall, according to the following equation:

$$Y = 1612.64 - 50.81X_1 + 0.45X_2$$

where Y is dead shoot biomass (g/m^2), X_1 is mean air temperature (°C) and X_2 is monthly rainfall (mm). This relationship was significant ($r = 0.67$, $P<0.05$). The dead shoot biomass increased considerably in the post-monsoon period and peaks occurred in November–December.

The occurrence of maximum litter fall could be due to the presence of tall grass and trampling by grazing animals resulting in increased transfer from dead shoot to litter as reported by Sims *et al.* (1978). The fluctuation in the amount of litter throughout the year is the net result of litter production and disappearance (Singh and Yadava 1974).

The accumulation of below-ground biomass showed a bimodal pattern of growth, the first peak occurring in February and the second in July. Similar observations have been made by Sah and Ram (1989) in temperate grassland. The maximum below-ground biomass was found during the month of January (winter), probably because of translocation of primary materials from live shoots to the below-ground parts. Similar reports have been made by Karunaichamy and Paliwal (1989) for protected grazing lands of the Madurai. The reduction in below-ground biomass in March–May may be due to the partitioning of nutrients towards live shoots to promote the rapid growth (11.4 g/m^2/d) of these tall grasses. Clipping also stimulates partitioning of nutrients towards shoots to promote growth as reported by Stout and Brooke (1985).

A comparison of the net above-ground and below-ground production for certain Indian grasslands is given in Table 1. The above-ground net production of 1212 g/m^2 was comparable with that reported from the temperate grassland of central Himalaya (Sah and Ram 1989). In the humid tropical region, Ramakrishnan and Ram (1988) have recorded below-ground production

Table 1. Comparison of net annual primary production and annual rainfall in the present study with data from the literature.

Site	ANP[1]	BNP[2]	TNP[3]	Rainfall	Source of data
	(g/m^2)	(g/m^2)	(g/m^2)	(mm)	
Pilani	217	61	278	391	Kumar and Joshi (1972)
Kurukshetra	2407	1131	3538	790	Singh and Yadava (1974)
Madurai	984	2897	3881	575	Karunaichamy and Paliwal (1989)
Rudranath	492	328	820	1586	Ram *et al.* (1989)
Gopeshwar	1184	706	1890	1787	Sah and Ram (1989)
Cherrapunji	579	990	1569	10 373	Ramakrishnan and Ram (1988)
Kalikesam	1212	244	1456	1496	Present study

[1] Above-ground net primary production.
[2] Below-ground net primary production.
[3] Total net primary production.

to be more than double the above-ground production because of the efficient uptake of nutrients in situations of low soil fertility. This may be also due to poor soil moisture retention in spite of higher precipitation.

In the present study, turnover rate appeared to be rapid. In general semi-arid grasses have lower turnover rates than those in humid regions. Similar observations were made by Coupland (1979) and Sims and Singh (1978a). Table 2 gives the annual balance sheet of dry matter at Kalikesam. The value for 'unaccounted for' (480.9 g/m^2) is transfer to total disappearance through dead shoots, litter and litter disappearance (LD) compartments. Golley (1965) has reported some direct transfer may also occur from the live compartment to litter compartments, mainly through the wastage of green vegetation by insects (Mitchell 1973). Some of the 'unaccounted for' could be due to respiration by plants in dry periods when they cannot photosynthesise. Struik (1965) suggested some material may also be translocated downward to aid the plants in surviving the unfavourable growing season.

System transfer function (STF) is the factor by which the system block multiplies the input to generate the output (Golley 1965) and reflects the orientation of the functioning of an ecosystem in space and time (Sims and Singh 1971). The net accumulation and disappearance of dry matter in the present grassland are shown in Figure 3 and the system transfer functions are given in Table 3. Of the total input of 3.99 $g/m^2/d$ into the system, about 83% and 17% were channelled to live shoots and below-ground. About 29% of above-ground net production was transferred to dead shoots and 47% to litter.

Table 2. An annual balance sheet of dry matter in a humid grassland of Western Ghats in southern India.

Component	g/m^2
Above-ground net primary production	
Initial biomass	34.6
Above-ground net production	1211.8
Transfer to dead shoots	352.3
Biomass at the end	413.2
Unaccounted for	480.9
Dead shoots	
Initial amount of dead shoots	112.0
Production of dead shoots	352.3
Transfer to litter	163.4
Dead shoots at the end	300.9
Litter	
Initial amount of litter	162.3
Litter production	163.4
Litter disappearance	60.9
Litter at the end	264.8
Below-ground net primary production	
Initial below-ground biomass	84.0
Below-ground net production	246.8
Disappearance of below-ground biomass	231.0
Below-ground biomass at the end	99.8

Table 3. System transfer functions of a humid grassland of Western Ghats in southern India.

Compartments From (Input)	Compartments To (Output)	System transfer functions (STF)
TNP	ANP	0.83
TNP	BNP	0.17
TNP	TD	0.22
TNP	L	0.11
ANP	SD	0.29
ANP	L	0.14
SD	L	0.47
L	LD	0.58

TNP = Total net production
ANP = Above-ground net production
BNP = Below-ground net production
L = Litter
SD = Dead shoot
LD = Litter disappearance
TD = Total disappearance

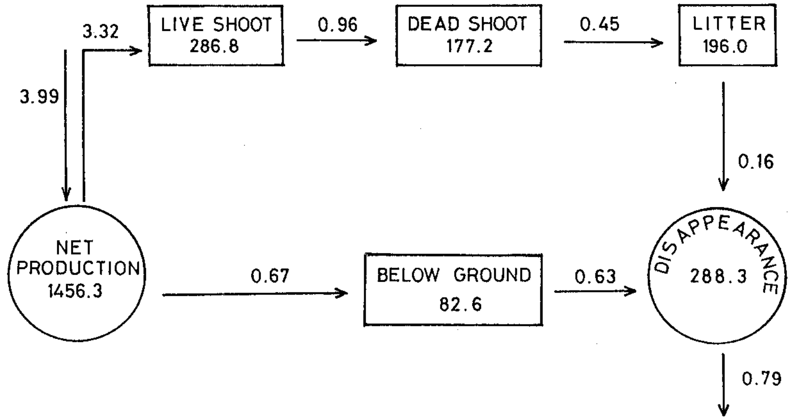

Figure 3. Diagram depicting net dry matter flow through the various compartments in humid grassland of Western Ghats in southern India. Numbers in boxes are the mean annual standing crop ($g/m^2/yr$); numbers in circles are total net primary production and disappearance; numbers on the arrows are net flux rates in $g/m^2/d$.

Transfer of live shoots into dead shoot compartment and that of dead shoots into the litter compartment was about 76%. Thus, there was a net accumulation in the live shoot compartment that occurred during the one year of present study. The rate of disappearance of litter was 0.16 $g/m^2/d$ and that of below-ground was 0.63 $g/m^2/d$. The sum of these values gives a total disappearance of 0.79 $g/m^2/d$ which was 22.3% of the total input for the humid grassland at Kalikesam.

There was a net surplus of organic material as the rate of disappearance was slower than the rate of dry matter accumulation. Similar findings have been reported in Pilani and Kurukshetra (Kumar and Joshi 1972; Singh and Yadava 1974). This accumulation of surplus organic matter could result in the advancement of the seral grassland to woodland condition. In central Himalayan, high altitude grasslands total output is similar to input indicating that the grassland is approximately in equilibrium (Ram *et al.* 1989). Differences between the two grasslands could be due to differences in intrinsic, climatic, edaphic and species compositions as reported by Gupta and Singh (1982) and Ram *et al.* (1989). Thus, the present grassland showed a net accumulation of surplus organic matter, which indicated the seral nature of the grassland. Moderate grazing in humid climates often increases the above-ground net primary production through tillering and increased diversity. We suggest that with proper management, degradation of the grassland ecosystem can be minimised to maintain the stability and diversity of these grassland ecosystems.

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