Tropical Ecology **41**(1): 33-39, 2000 ISSN 0564-3295
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Fire and nutrient dynamics in a *Heteropogon contortus* grazingland of Garhwal Himalaya

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Abstract: The paper reports standing state and cycling of nutrients (N, P, & K) in burnt and unburnt *Heteropogon contortus* grazingland of Garhwal Himalaya. More nutrients were found in living plant parts than standing dead and litter. Nitrogen was outrival in aboveground live shoots than roots and reverse was true for phosphorus and potassium. Fire reduced nitrogen in soil and plant parts and increased phosphorus and potassium contents. Uptake of nitrogen was 0.97 and 1.14 g $m^{-2}y^{-1}$ on burnt (BG) and unburnt (UG) plots, respectively, and 98.4 and 84.9% nitrogen was released through litter and root decomposition on respective plots. Phosphorus and potassium uptake was more on burnt plot than unburnt one. Uptake of phosphorus was 0.72 and 0.66 g $m^{-2}y^{-1}$, respectively, on BG and UG plots. Of the total uptake, 90.5 and 83.9% was released in soil via root and litter decomposition. Out of the total uptake of phosphorus (1.56 g m^{-2}-BG; 1.36 g m^{-2}-UG), 22.5 to 40.3% was directed to belowground production (BNP). Release of potassium through root and litter decomposition was 97.9 and 85.0%, respectively, on BG and UG plots. Burning of vegetation stimulated nutrients use efficiency as compared to protection against burning treatment.

Resumen: El artículo reporta el contenido y ciclaje de nutrients (N, P & K) en pastizales quemados y no quemados de *Heteropogon contortus* del Garhwal Himalaya. La mayoría de los nutrients se encontraron en las partes vivas de la planta más que en las partes muertas y en la hojarasca. El nitrógeno fue mayor en las partes aéreas más que en las raíces y lo inverso ocurrió para el fósforo y el potasio. El fuego redujo el nitrógeno en el suelo y en las partes de la planta e incrementó el contenido de fósforo y potasio. El ingreso de nitrógeno fue de 0.97 y 1.14 g m^{-2} año^{-1} en las parcelas quemadas (BG) y no quemadas (UG), respectivamente, y 98.4 y 84.9% del nitrógeno fue liberado a través de la hojarasca y descomposición de las raíces en las respectivas parcelas. El ingreso del fósforo y del potasio fue mayor en las parcelas quemadas que en las no quemadas. El ingreso de fósforo fue de 0.72 y 0.66 g m^{-2} año^{-1}, en las parcelas BG y UG, respectivamente. Del ingreso total, 90.5 y 83.9% fue liberado en el suelo vía descomposición de raíces y hojarasca. Del total del ingreso de fósforo (1.56 g m^{-2} – BG; 1.35 g m^{-2} – UG), de 22.5 a 40.31% fue dirigido a la producción hipógea (BNP) La liberación de potasio a través de la descomposición de raíces y hojarasca fue de 97.9 y 85.0% en las parcelas BG y UG, respectivamente. La quema de la vegetación estimuló el uso eficiente de los nutrientes comparado con la protección en el tratamiento contra la quema.

Resumo: Este trabalho reporta o estado de equilíbrio e a circulação de nutrientes (N, P, K) numa estação de pastagem, queimada e não queimada, de *Heteropogon contortus* no Garhwal, Himalaias. Nas partes vivas das plantas foram encontrados mais nutrientes do que nas partes mortas aéreas e na folhada. O teor em azoto era o mais elevado nos lançamentos vivos aéreos do que nas raízes e o reverso era verdadeiro para o fósforo e o potássio. A queimada reduziu o azoto no solo e em partes das plantas enquanto aumentou o teor em fósforo e potássio. A absorção do azoto foi de 0,97 e 1,14 g.m^{-2}.y^{-1} nas parcelas queimadas (BG) e não queimadas (UG), respectivamente. Em relação ao azoto libertado através da decomposição da folhada e das raízes naquelas parcelas, os valores foram respectivamente de 98,4 e 84,9%. Os valores da absorção do fósforo e do potássio foi maior nas parcelas queimadas quando comparado com as não queimadas. A absorção do fósforo foi de 0,72 e 0,66 $g.m^{-2},y^{-1}$, respectivamente nas parcelas BG e UG. Da absorção total, 90,5 e 83,9% foram libertados no solo através da decomposição das raízes e da folhada. Da absorção total do fósforo (1,56 $g.m^{-2}$ – BG; 1,35 $g.m^{-2}$ – UG), 22,5 a 40,3% foi dirigido à produção subterrânea (BNP). A libertação do potássio através da decomposição de raízes e da folhada foi de 97,9 e 85,0%, respectivamente para as parcelas BG e UG. A queima da vegetação estimulou a eficiência do uso dos nutrientes quando comparada com as parcelas protegidas da queimada.

Key words: Fire, Garhwal, Himalaya, grazingland, nutrients, release, uptake.

Introduction

The effects of fire on the nutrients of an ecosystem depend on the type and frequency of fire, the fuel load, time and season of burn, nature of the plant tissues burnt, topography, successional status of the community and post-fire climatic and biotic conditions acting thereupon (Daubenmire 1968; Habeck 1976; Semwal & Mehta 1996; Wright 1974). Vegetation burning is not bad and must be seen as an overall management opportunity if applied scientifically (Tiwari *et al.* 1989). Fire related vegetation transforms low soil fertility conditions due to intense leaching and run-off losses. Perturbation due to fire and possible constraints related to nutrients cycling are factors that may determine the stability of grassland types (Ram & Ramakrishnan 1988, 1992). Despite the importance of fire as a land management tool, in Garhwal Himalaya there has been a little research into its effects on nutrient dynamics (Agarwal & Tiwari 1987, 1988). The work presented in this paper was, therefore, undertaken to elicit the nutrient dynamics in terms of N, P & K under burnt and unburnt situations in a *Heteropogon contortus* grazingland of Garhwal Himalaya.

Materials and methods

Experimental plots

Two grazinglands, one burnt (BG) and other unburnt (UG) with an area (plot) of 200 x 200 m each, were selected at Srinagar, Garhwal Himalaya (30^{o}12 15 - 30^{o}15 N Lat. and 78^{o}50 E Long., and 800 - 1000 m amsl in south-east slope). The experimental area is a successional grazingland with scattered trees of pine (*Pinus roxburghii*) associated with *Bombax ceiba, Dalbergia sissoo, Mallotus philippensis*, etc., and gives a physiognomic appearance of low savannah as pointed out under the heading formation Class I. J. by Misra (1968). Burnt plot experienced man caused surface/ground fire on June 25, 1992 whereas, other remained unburnt. The study was carried out for a period of one year from July 1992 until July 1993 at 1-mo intervals.

Climate

The study area enjoys the submontane climate with exhausting summers and severe winters. Climate is monsoonic with three distinct seasons in a year *viz.*, rainy (mid June-September), winter (October-February) and summer (March - mid June). Rainy season accounts for two-third of the annual rainfall. Pluviothermic diagram (Fig. 1) indicates the alternate dry and wet months during the study period.

Geology and soil

Geologically, the area is located in the north limb of Dudhatoli syncline and the rocks belong to Pauri phyllite and Khirsu quartzite formation of Kumaun super group (Kumar & Agarwal 1975). Soil is mostly sandy along the bank of river Alaknanda and varies from sandy loam to clayey loam in terraces used as grazinglands along the foothills.

Sampling of biomass and nutrient analysis

Phytomass sampling was carried out every month from July 1992 until July 1993. On each sampling date, 20 quadrats of 20 x 20 cm were laid

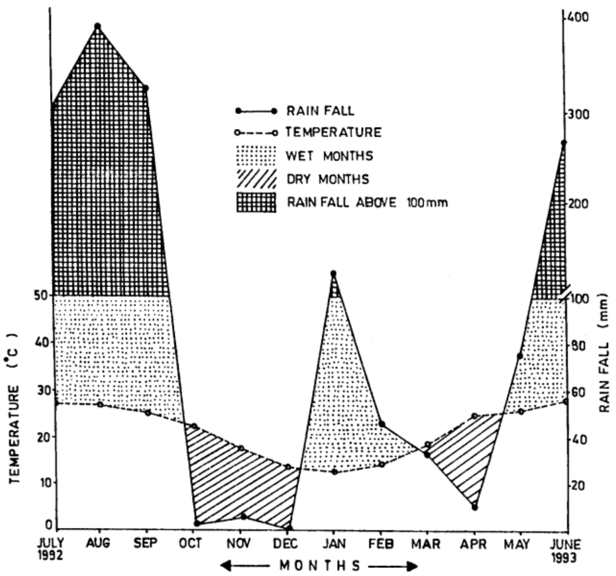

Fig. 1. Pluviothermic diagram for Srinagar (Garhwal) showing wet and dry months during study period.

randomly on each of the study plots and aboveground standing crop was clipped. The plant material was then separated into live and dead shoots. Litter from each quadrat was collected separately. All the materials were oven dried at 80°C till constant weight. From each quadrat, soil monoliths of 20 x 20 x 20 cm were dug out and analysed for belowground biomass following Singh & Yadava (1974). Monthly data were geared to different seasons. The concentrations of nutrients were determined in representative bulk samples of the vegetation components. Nitrogen contents were determined using kjeldahl digestion procedure while phosphorus and potassium contents were determined using spectrometer following digestion with nitric acid. The total element quantities of each compartment was computed by multiplying concentrations x dry mass.

Uptake, transfer and release of nutrients

Net uptake of nutrients was computed as :

$$\text{Net uptake} = \sum_{i\,1}^{n} \text{NGB} + \sum_{i\,1}^{n} \text{NDB} + \sum_{i\,1}^{n} \text{NRB}$$

where, NGB, NDB and NRB are the positive increments in nutrients of live shoot, dead shoot and belowground biomass, respectively, over the sampling intervals.

Transfer rates between various compartments and the release of nutrients through root and litter decomposition were computed following Tiwari (1985). A sum of root and litter disappearance was considered as the total release of nutrients by plants in the system. The difference between total uptake and release was considered as retention.

Results

Nitrogen

Live shoot compartment exhibited a seasonal trend in the standing state of nitrogen on both the study plots. It peaked (0.433 ± 0.043 and 0.500 ± 0.075 g m^{-2}) in rainy season and lowered down to 0.274 ± 0.058 and 0.320 ± 0.008 g m^{-2} in summers, respectively, on BG and UG. More nitrogen was observed on UG than BG. Standing dead compartment did not show such a definite trend.

Higher amount of nitrogen in litter (0.151 ± 0.037 BG and 0.238 ± 0.058 UG) was recorded in winter season on BG and UG, respectively, and belowground compartment followed the same trend.

Phosphorus

It culminated in live shoots in rainy season amounting to 0.268 ± 0.05 and 0.277 ± 0.038 g m^{-2}, respectively, for BG and UG plots. On the other hand winters and rains showed its peak values 0.138 ± 0.033 g m^{-2}; BG and 0.086 ± 0.027 g m^{-2}; UG respectively, in the dead shoots. Litter had maximum values in winters on both plots and minimum values in summers and rains, respectively, on BG and UG. There was no definite trend for roots.

Potassium

It had outrank amount (0.511 ± 0.16 g m^{-2}) in rainy season on BG and fall short of (0.329 ± 0.17 g m^{-2}) in summer season on UG. There was no significant variation in dead shoots. In litter it was maximum (0.069 ± 0.020 g m^{-2} BG and 0.046 ± 0.015 g m^{-2} UG) in winter season. Potassium content was higher on the unburnt than burnt plot in the roots.

Uptake, transfer and release of nutrients

Net uptake of nutrients in ANP and BNP are presented in Table 1. Plant and soil components

Table 1. Uptake, transfer and release of nutrients (g $m^{-2}y^{-1}$).

Compartment	Nutrients/site					
	Nitrogen		Phosphorus		Potassium	
	BG	UG	BG	UG	BG	UG
Uptake of nutrients in aboveground net production	0.522	0.625	0.566	0.351	1.212	0.810
Uptake of nutrients in belowground net production	0.450	0.516	0.154	0.316	0.352	0.547
Total uptake of nutrients	0.972	1.141	0.720	0.667	1.564	1.357
Transfer from live to standing dead compartment	0.539	0.641	0.556	0.324	1.217	0.703
Transfer from standing dead to litter compartment	0.551	0.597	0.556	0.318	1.213	0.701
Release of nutrients through litter decomposition	0.557	0.571	0.558	0.310	1.216	0.684
Release of nutrients through root decomposition	0.399	0.398	0.094	0.250	0.316	0.470
Total release of nutrients	0.956	0.969	0.652	0.560	1.532	1.154

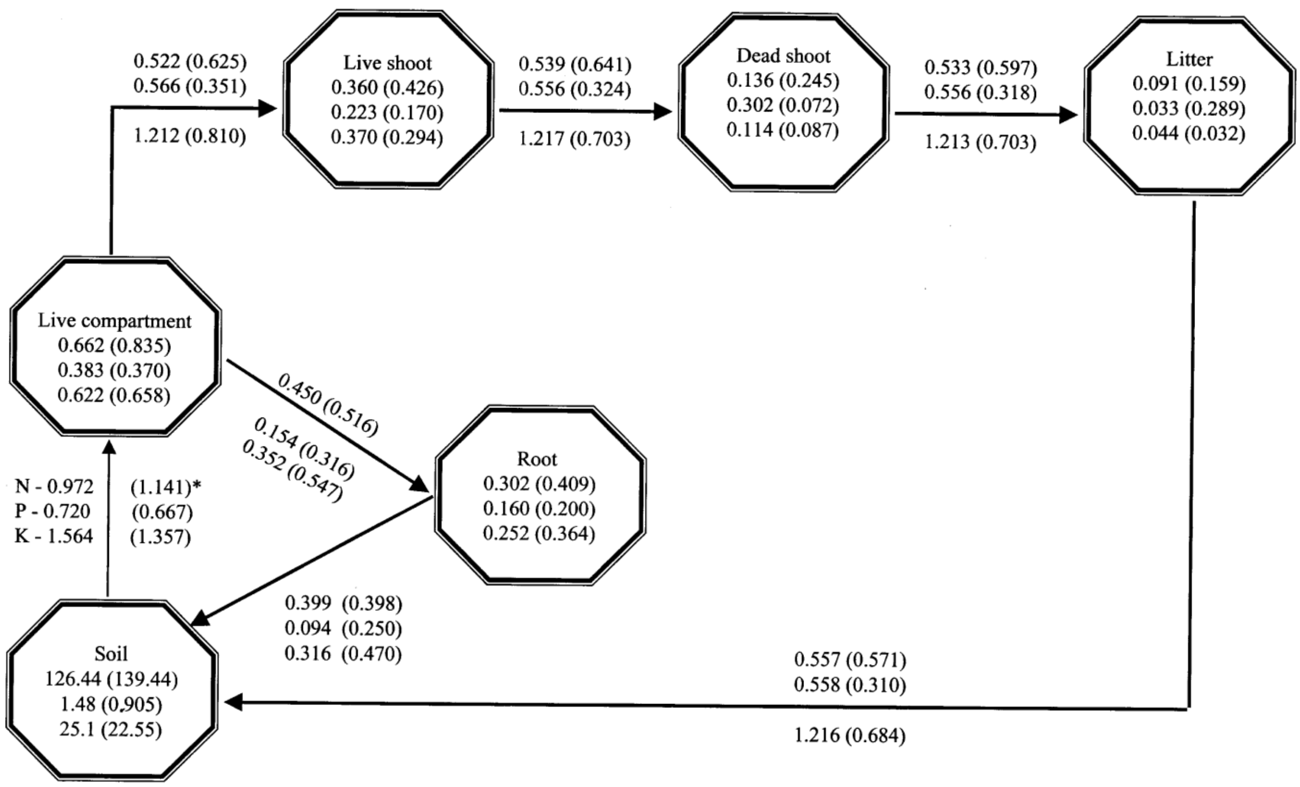

Fig. 2. Cycling of nutrients (N, P & K) in soil-vegetation components on BG and UG plots. (Polygons represent the storage (g m^{-2}) and arrows indicate the transfer rate (g $m^{-2}y^{-1}$), *values in parentheses are for UG plot.

with different transfer and release rates are arranged in polygon and arrow model in each vegetational component with an input and output (Fig. 2). The values mentioned in the polygons are the average standing state of nutrients and those mentioned along the arrows are the annual transfer rates between compartments. The formers are not as informative as latter since they are only an approximate measures of storage capacity of the compartments.

Uptake of nitrogen was 0.972 and 1.141 g $m^{-2}y^{-1}$, respectively, on BG and UG plots. Of the total uptake in ANP, 103.0% (BG) and 102.6% (UG) was transferred to standing dead compartment. Whereas, 46.0 and 45.2% was associated with belowground net production (BNP). 98.4 and 84.9% nitrogen was released through litter and root decomposition on respective plots. Retention was 0.016 and 0.172 g $m^{-2}y^{-1}$, respectively, on BG and UG.

Uptake of phosphorus was 0.720 and 0.667 g $m^{-2}y^{-1}$, respectively, on BG and UG, and of this 21.4 and 47.4% was associated with BNP on the respective plots. 98.2 and 92.3% of ANP was directed to standing dead compartment. On BG plot 100% of SD compartment was transferred to litter and it was 98.1% on UG. 61.04 and 79.1% phosphorus of BNP was released through root decomposition. Total release via litter and root decomposition was 90.55 and 83.96% on BG and UG, respectively.

Uptake of potassium was higher on BG (1.54 g $m^{-2}y^{-1}$) than UG (1.36 g $m^{-2}y^{-1}$) and of this, 22.52 and 40.31% was directed respectively to BNP. More than 100% potassium of ANP was transferred to SD compartment on BG and it was 86.79% on UG. Almost 100% (99.67 BG; 99.72 UG) of the SD compartment was transferred to litter. Total release through root and litter decomposition was higher on BG (97.9%) than on UG (85%).

Discussion

Amounts of nutrients in an ecosystem may be relatively stable or it may be changing in quantity depending on the net gain and loss of nutrients by various input and output processes. Fire may cause direct losses through the transfer of the nutrients to the atmosphere as gases and particulates (Raison *et al.* 1985), while indirect losses may result from erosion of ash and soil during storms (Kellman *et al.* 1985). In the present study nitrogen concentration in live shoots was more than the roots across the plots. It decreased as the live shoot turned to litter stage via standing dead. Nevertheless, nitrogen concentration was higher on UG than BG (Table 2). It is understandable as nitrogen is volatilized during burning of vegetation (Lloyd 1971), and thus BG showed lower concentration than UG. The decrease in nitrogen concentration may also lead to the loss of soil microflora and fauna which are essential for the growth and development of higher plants (Khanna 1991; Naidu & Srivasuki 1994).

Live shoots showed higher phosphorus concentration with gradual decrease as the live shoot moved to litter stage. Contrary to nitrogen, it was more on BG in all the components. This might be due to increased amount of phosphorus in soil after fire as also observed by Agarwal & Tiwari (1988) while working on the effects of fire in a Garhwal Himalayan grazingland. Higher amount of phosphorus in roots on UG appears due to regular accumulation owing to continuous photosynthetic activity on unburnt plot. Live shoots shared major amount of potassium than roots on both plots. Further, relatively higher amount of potassium in live shoots on BG seems to be associated with fire which increased the potassium content on burnt plot.

Sharp decline in the concentration of elements as plant material moves to litter stage is due to weathering or leaching of the respective elements by rain interception or by translocation before moving into dead stage (Billore & Mall 1976; Carlisle *et al.* 1967). In the present investigation, fire reduced the concentration of nitrogen from aboveground to belowground compartments. Whereas, concentration of phosphorus and potassium increased in all the compartments after fire. Several authors reported an increase of soil min-

Table 2. Biomass (g m^{-2}) and nutrient concentration (%) on BG and UG plots; data in parentheses are for UG plot.

Season/ Component	Shoot				Litter				Belowground			
	Biomass	N	P	K	Biomass	N	P	K	Biomass	N	P	K
Rainy (Jul-Sep)	313±49 (311±19)	.18±.01 (.27±.05)	.12±.02 (.10±.01)	.206±.06 (.101±.02)	53±4 (45±6)	.13±.10 (.22±.05)	.05±.006 (.03±.005)	.05±.01 (.04±.01)	287±53 (302±19)	.07±.010 (.09±.01)	.05±.002 (.06±.008)	.08±.008 (.11±.01)
Winter (Oct-Feb)	275±35 (234±35)	.19±.04 (.29±.04)	.13±.04 (.08±.01)	.166±.05 (.170±.05)	41±3 (40±1)	.36±.08 (.59±.03)	.09±.014 (.09±.02)	.16±.04 (.11±.03)	261±44 (239±35)	.16±.05 (.21±.05)	.06±.01 (.06±.01)	.10±.02 (.13±.03)
Summer (Mar-Jun)	273±10 (200±12)	.14±.02 (.24±.04)	.08±.02 (.11±.03)	.155±.08 (.214±.08)	67±5 (53±7)	.06±.03 (.21±.007)	.01±.007 (.05±.009)	.04±.007 (.05±.002)	252±13 (223±24)	.09±.006 (.17±.01)	.08±.01 (.09±.02)	.09±.01 (.18±.04)

eral nutrients following fires in different ecosystems which ultimately affects the nutrient level of plant (Agarwal & Tiwari 1987; Chandler *et al.* 1983; Christensen 1987; DeBano 1991; Lloyd 1971; Pyne 1984). Such an increase was explained by an enrichment of soil by ash, which would represent one of the reservoirs for minerals (Christensen 1987).

Analysis of living material and litter from burnt and unburnt situations gives an estimate of recovery of the vegetation over the period following fire (Lloyd 1971). Present study indicates that the amount of nutrients differs markedly among the different compartments on BG and UG. Recovery of nutrients did not appear to have completed during the study period. Lloyd (1971) also observed that the recovery of the nutrient content of a herbaceous community completed within two years of burning. Further, in grasslands, litter fall to the ground and decomposition of belowground parts are normally considered as the two important routes of nutrient circulation. However, in forest and forest associated grazingland ecosystems, the transfer of nutrients from root to soil can not be documented exactly because of the practical difficulties involved in recording.

Uptake of nitrogen was higher on UG than BG and reverse was true for phosphorus and potassium. In some cases it has been seen that the transfer of nutrients was more at compartmental level than that of the uptake. Higher transfer at various compartmental levels is attributed to channeling of nutrients from previous years. Nutrients output to input ratio gives an indication of nutrient use efficiency. The study indicates that burning stimulates nutrient use efficiency as compared to protection against burning treatment. It is concluded from this study that unburnt environment favours the retention of nutrients in plant parts while burning of vegetation accelerates nutrient cycling through rapid release.

Acknowledgements

Authors are thankful to Prof. R.D. Gaur, Head Department of Botany for necessary facilities and encouragement. Thanks are also due to Dr. G.C.S. Negi for critically going through the manuscript. Financial support from Council of Scientific & Industrial Research (CSIR) New Delhi to the first author is gratefully acknowledged.

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