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Effect of *Albizzia lebbeck* plantation on the nutrient cycling in a semi-arid grazingland

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Abstract: In this study, monthly changes in concentrations of various nutrients (N, P, K, Ca & Mg) and their uptake, accumulation, transfer and release in both plant parts and soil were studied in grasses grown under *Albizzia* plantation and in the open grazing land in the semi-arid region of Madurai. At both sites, the maximum concentration of all nutrients were recorded in the live shoot, followed by dead shoot, below ground and litter. The average nutrient accumulation in the plant parts as well as in the soil was in the order of N>K>Ca>Mg>P. Among the sites, the nutrients concentration in plant components and the uptake from the soil were significantly higher ($P<0.05$) in the plantation site than in the open grazing land. The soil moisture content also showed significant increase under *Albizzia* plantation than in the open grazingland. Of the total uptake about 80% of nutrients, were transferred to above ground plant parts and very little was transferred to below ground parts. At both sites, the nutrients return to the soil through root was lower than that of litter disappearance. The study reveals that *Albizzia* trees can increase the nutrient content of understorey grasses by their rapid leaf turnover and decomposition of nutrient rich litter, which can result in significant increase in soil fertility.

Resumen: En este trabajo, los cambios mensuales en las concentraciones de varios nutrientes (N, P, K, Ca y Mg) y su captación, acumulación, transferencia y liberación tanto en las plantas como en el suelo fueron estudiados en pastos que crecen bajo la plantación de *Albizzia* y en la tierra abierta de pastoreo en la región semiárida de Madurai. En ambos sitios, las máximas concentraciones de todos los nutrientes fueron registrados en el vástago vivo, seguido por el vástago muerto, las partes subterráneas y el mantillo. La acumulación promedio de nutrientes tanto en las partes vegetales como en el suelo tuvo el siguiente orden: N > K > Ca > Mg > P. Entre los dos sitios, la concentración de nutrientes en los componentes vegetales y la captación desde el suelo fueron significativamente más altos ($P<0.05$) en el sitio de la plantación que en la tierra abierta de pastoreo. El contenido de humedad en el suelo también mostró un incremento significativo bajo la plantación de *Albizzia* con respecto a la tierra de pastura. De la captación total, aproximadamente 80% de los nutrientes fueron transferidos a las partes aéreas de las plantas y muy poco se transfirió a las partes subterráneas. En ambos sitios la reincorporación de nutrientes al suelo a través de la raíz fue más bajo que la desaparición del mantillo. El estudio muestra que los árboles de *Albizzia* pueden incrementar el contenido de nutrientes en los pastos del sotobosque gracias a su rápido recambio foliar y la rápida descomposición de su mantillo rico en nutrientes, lo cual puede resultar en un incremento significativo en la fertilidad del suelo.

Resumo: Neste estudo foram estudadas as mudanças na concentração de vários nutrientes (N, P, K, Ca & Mg) e a sua absorção, acumulação, transferência e libertação nas componentes das plantas e no solo em pastagens crescendo sub-coberto de plantações de *Albizzia* e em past-

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agem aberta na região semi-árida de Madurai. Em ambas as estações, a maior concentração de todos os nutrientes foi registada nos rebentamentos vivos, seguida pela dos rebentamentos mortos no subsolo e folhada. A acumulação média de nutrientes nas componentes das plantas assim como no solo foi da seguinte ordem: N>K>Ca>Mg>P. Entre as estações, a concentração de nutrientes nas componentes das plantas e a absorção do solo foi significativamente alta (P<0,05) na plantação em comparação com a pastagem livre. O teor em água no solo também se mostrou significativamente aumentado sob plantação de Allbizia do que na pastagem livre. Da absorção total cerca de 80% dos nutrientes foram transferidos para as componentes aéreas das plantas e muito pouco foi transferido para as componentes subterrâneas. Nas duas estações, a taxa de retorno dos nutrientes através das raízes foi menor do que a resultante da folhada. O estudo revela que as árvores de *Albizzia* podem aumentar o teor em nutrientes das ervas sob coberto pela sua rápida rotação de folhagem e decomposição da folhagem rica em nutrientes e de que resulta um aumento significativo da fertilidade do solo.

Key words: Litter disappearance, nutrient dynamics, open grazingland, plantation, root disappearance, semi-arid region.

Introduction

Establishment of suitable tree species in the degraded grasslands is one of the ways to improve grassland productivity. However, they may have both positive as well as negative effects. Low herbaceous productivity, under tree canopies than the open grasslands have been reported by Dye & Spear (1982), Walker & Noy-Meir (1982), whereas in other instances higher grassland productivity under canopies has been observed by Holland (1980), Bernhard-Reversal (1982) and Maranga (1984). The increase in productivity of understorey vegetation under plantation depends upon the nature of the tree species selected. The choice of species may affect understorey colonization in several ways as tree species will differ in their canopy architecture and influence the understorey light, temperature and humidity regimes (Parrotta 1993); rates of leaf litter production, decomposition and litter chemistry (Suresh & Vinaya Rai 1988); and influence on soil biological activity and other aspects of soil fertility. Sarmiento (1984) studied the importance of trees in creating horizontal structure and influencing the dynamics of savanna ecosystems. However, reports on the effects of trees on the nutrient dynamics of grassland are limited. The present study deals with the effects of *Albizzia* plantation on nutrient dynamics and soil fertility of the grazing land in the semi-arid environment.

Study site

The study site is located at Madurai (10° 00″ N longitude, 78° 10″ E latitude, 132 msl). The climate of Madurai is semi-arid. The mean maximum temperature ranged from 28.7°C in December 1992 to 37.9°C in April 1992. The mean minimum temperature ranged from 19.2°C in January 1992 to 26.3°C in June 1992. Annual rainfall during the study period was 1136 mm and the relative humidity ranged between 21% and 73%. The soil is reddish brown, laterite sandy loam. The pH of the soil ranged between 7.0 and 8.3.

The study was conducted at the Biomass Research Center, Madurai Kamaraj University. The plantation system, where the sampling was done, was composed of 14 years old *Albizzia lebbeck* trees with the associated herbaceous vegetation mostly dominated by *Heteropogan contortus*, with the density of 100 trees per hectare. The mean dbh was 15 cm. The trees were spaced at 3 m in a grid pattern. The adjacent open grazingland, dominated by *Heteropogan contortus*, was considered as control. *Aristida adscencionisis* and *Lpidogathis pungens* were the co-dominants in the open grazingland, while *Aristida adscencionisis* and *Indigofera aspalathoides* were the co-dominants in the plantation system. Both the plantation system and the open grazingland were protected from grazing during the study period.

Material and methods

Sampling of vegetation and soil

The biomass was estimated by harvest method (Milner & Hughes 1968). The sample was harvested at monthly intervals from 10 randomly laid quadrats of 0.5 m^2. Litter was collected from each harvested plot. The above ground materials were separated into live shoot, standing dead and litter. From the harvested quadrat, the belowground biomass was estimated by excavating 25 x 25 x 30 cm monolith from three randomly laid quadrats. The roots are separated by washing the soil with tap water using 2 mm sieve. All samples were oven dried at 60°C to constant weight and weighed. A portion of dried samples was powdered and used for nutrients analysis.

The soil samples were collected separately on each sampling month from three different places by digging pits of 25 x 25 x 30 cm at the experimental site. The samples were dried, sieved (2 mm) and used for nutrients analysis. Soil moisture was determined by gravimetric method and soil pH was measured by using a pH meter.

The total nitrogen and phosphorus contents of both soil and plant samples were analyzed by using Auto analyzer (Gradko International Ltd., U.K.). Other nutrients (K, Ca, Mg) were analyzed using Atomic Absorption Spectrometer (Perkin – Elmer 1982, Model 5000).

Nutrient transfers between soil and vegetation compartments

The nutrient storage was calculated by multiplying concentration (mg g^{-1}) of respective nutrients with biomass (g m^{-2}). Dry matter production and its transfers between vegetation compartments were calculated following balance sheet approach of Singh & Yadava (1974). The nutrient content per gram dry weight of soil was multiplied by the bulk density to obtain its storage in soil (g m^{-2} per 30 cm depth).

The annual mean nutrients concentration in live shoot and root were multiplied respectively with annual net aboveground and belowground production values, to obtain the estimates of aboveground and belowground nutrient uptake. Nutrient transfers from live shoot to dead shoot and from dead to litter were calculated by multiplying the annual mean nutrient concentration in dead shoot to litter (Bokari & Singh 1975). Nutrient release from litter was calculated by multiplying the annual mean nutrient concentration in litter with the quantity of litter that disappeared. Similarly, nutrient transfer from below ground parts to their disappearance were calculated by multiplying the annual mean nutrient concentration of root with the value of dry mass of root that disappeared during the year.

Statistical analysis

Student "t" test was used to test significant differences between the sites.

Results

Nutrient concentration in plant components

The monthly changes in N, P, K, Ca & Mg concentrations in vegetational components of the open grazinglands and the grassland community under plantation system are shown in the Figs. 1, 2 & 3. Maximum concentration of all the elements was recorded in the live shoots followed by dead shoots, below ground parts and litter. Concentration of N in the live shoots showed two peaks, one in June and another in December in both the communities. It ranged between 0.4% (January) and 1.3% (December) in the open grazingland and 0.9% (August and 1.8% (December) in the plantation site. N concentration in the below ground parts was maximum in December in both communities. Phosphorus concentration was lowest among the nutrients studied. The relative proportions of various elements differed considerably in different plant components. Significant increase ($P<0.05$) in nutrients concentration in plant components was observed in the grazingland under plantation than in the open site. At both the sites, the average nutrient concentration in the plant components were in the order of N>K>Ca>Mg>P.

Nutrient concentration in soil

Table 1 shows the seasonal variations in soil nutrients concentration and moisture content during the study period. Among the five elements, concentration of N was the highest and that of P the lowest. Analysis of variance showed that there was a significant difference in the nitrogen concentration between the sites ($P<0.001$). The soil nutrients were higher during winter followed by sum-

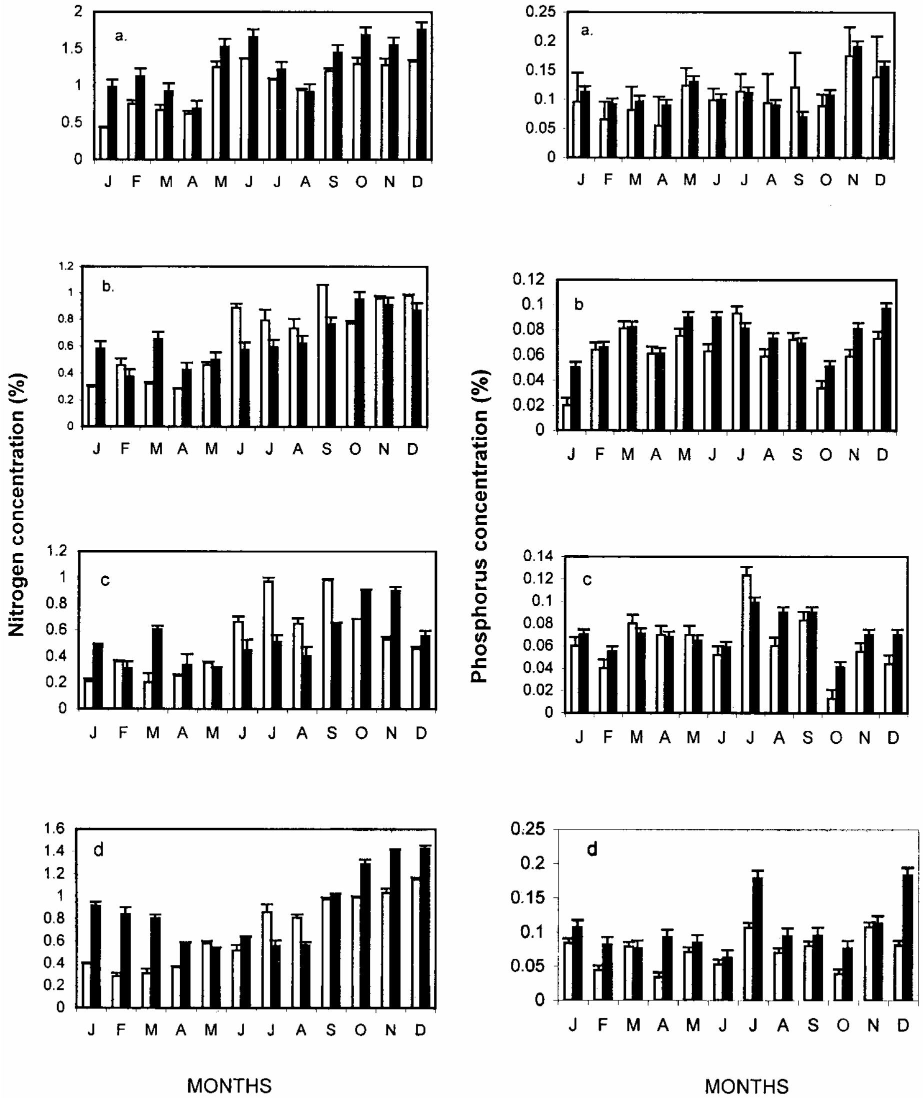

Fig. 1. Monthly changes in N and P concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (□) and grassland under *Albizzia* plantation (■).

mer and rainy season. At both the sites, the nutrient concentration in the soil was in the order of N>K>Ca>Mg>P. The soil moisture content also showed significant increase ($P<0.05$) under plantation than in the open grazingland.

Annual uptake, transfer and release of nutrients

Figs. 4a & b show the uptake, transfer and release of nutrients in the grazinglands. In the open grazing land the annual uptake of N, P, K, Ca & Mg by vegetation was 12.5, 1.3, 6.4, 9.7 and 2.1 g m^{-2} respectively, while in the plantation site, the corresponding values were 20.3, 1.9, 10.3, 18.7 and 4.4 g m^{-2}. Of the total uptake 80% of nutrients were transferred to the live shoot and very little and rest was transferred to the below ground parts. The return of all nutrients to soil through litter and roots was much lower than their uptake. At both the sites, the nutrients returned to the soil through roots was lower than the litter. Among the sites, the uptake of the nutrients were significantly higher in the grazingland under plantation than in the open grazingland.

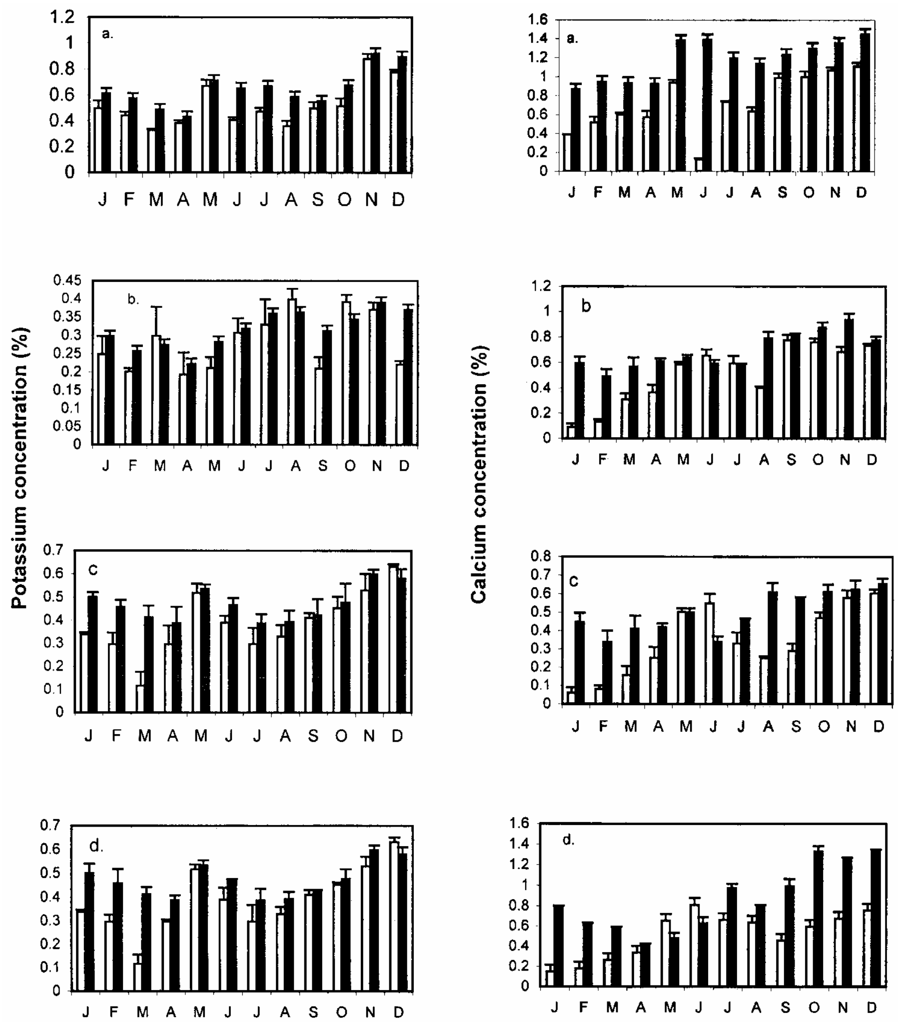

Fig. 2. Monthly changes in K and Ca concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (□) and grassland under *Albizzia* plantation (■).

Discussion

At both the sites, the maximum concentration of all elements occurred in the liveshoot followed by dead shoots, below-ground parts and litter. Similarly, Rychnovska (1979), Gupta *et al.* (1990) and Karunaichamy & Paliwal (1995) observed that the above ground live shoots contain higher percentage of elemental concentration than the other plant components. The decline in concentration of nutrients from live shoot to dead shoot is a common phenomenon in temperate (Callahan & Kucera 1981) as well as tropical grasslands (Chaturvedi *et al.* 1988). This decline has been attributed to the withdrawal of nutrients from the shoot during senescence (Clark 1977), weathering, leaching (Turkey 1970) and microbial activity (Nykvist 1959). Results of large number of studies revealed that nutrient concentration in below ground part is generally lower than the live shoot both in temperate (Agrawal 1988; Ohlson & Malmer 1990) and tropical grasslands (Billore & Mall 1976; Chadurvedi *et al.* 1988). The annual uptake of nutrients in both the grazinglands were in the order of N>Ca>K>Mg>P. The amount of nitrogen stored in the plant components was higher than the other nutrients. These differences may be attributed to their relative requirements in the

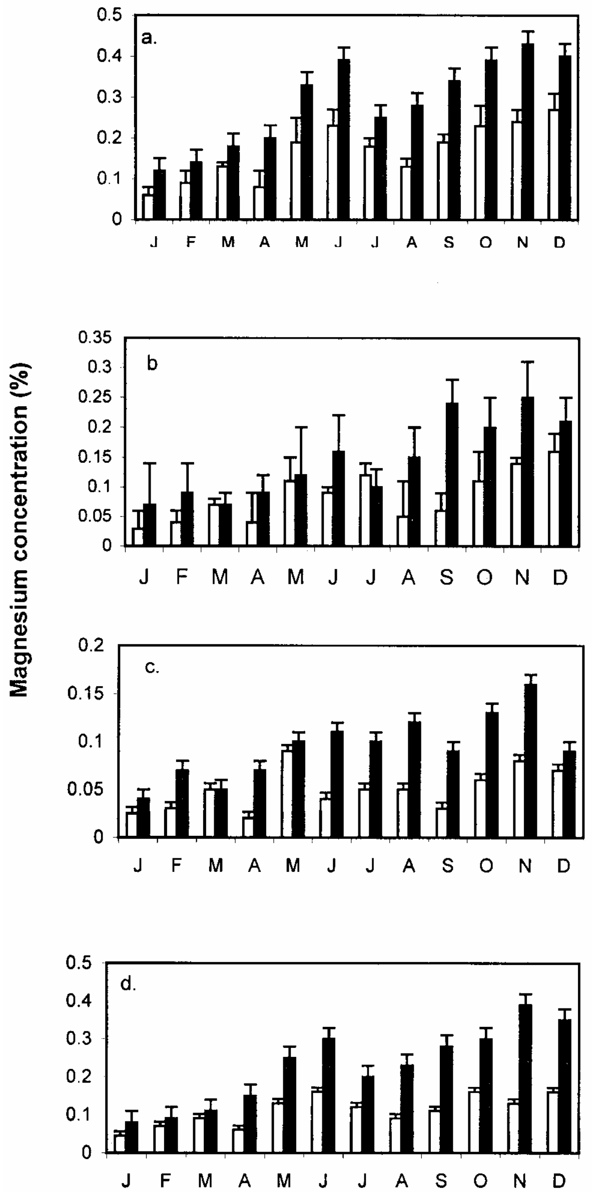

Fig. 3. Monthly changes in Mg concentrations in live shoot (a), standing dead (b), litter (c), and below ground (d) of the vegetation in open grazingland (□) and grassland under *Albizzia* plantation (■).

metabolic processes, or to their relative availability in the ecosystem (Agarwal 1988).

The nutrient concentrations in the plant components were significantly higher in the plantation site than in the open grazingland. Similar increase in nutrient concentration under tree canopies were also found by Kay & Leonard (1980) in California and by Wilson *et al.* (1990) in Australia. The higher concentration of nutrients in the plant components resulted from higher nutrient content of the soil. Under canopy the soil moisture status is increased, which increases the moisture content of the surface litter, litter break down and mineralisation of organic matter.

The uptake of nutrients were higher in the grassland under *Albizzia* plantation than in the open grazingland. This may be due to lower nutrient concentration in the open grazing land and also due to litter composition and types of micro organisms (Witkamp & Van der Drift 1961). The plantation system promotes nutrient cycling by taking up soil nutrients through tree roots and recycling them as litter, and root residue and helping to synchronize nutrient release with grass requirements by controlling the quality, timing and manner of addition of plant residue (Singh *et al.* 2000; Young 1991). The nutrients return to the soil through litter disappearance was lower than that of root disappearance.

Eastham (1988) observed that the evapotranspiration losses from pasture were highest under open area and decreased as the pasture was more shaded by the tree canopy. Because of low evapotranspiration rates, the soil moisture increased under canopy, which would improve the nutrient uptake from soil (Tisdale & Nelson 1975). Agarwal *et al.* (1976) studied the level of fertility under different plantations and the soil under open field conditions and he observed that soil profile below *P. cineraria* contains comparatively higher organic matter, total nitrogen, available phosphorus, soluble calcium, low pH, available micro nutrients and better mechanical composition of soil up to 120 cm depth. The soil fertility is maintained through decomposition of roots of trees and crops and litterfall, which inturn increase organic matter and biological activity of the soil by enhancing soil nutrient status (Szott *et al.* 1991; Singh *et al.* 2000). In the present study the increase of nutrients under canopies may be due to the nutrient input by tree litter.

Samarakoon *et al.* (1990) reported that shadded grasses have higher concentrations of N, P, K, Ca, Mg, Cu and Zn than unshaded grasses. In contrast to these results, Suresh & Vinaya Rai (1987) observed the inhibitory effect of certain tree species on the surrounding vegetation through production of chemical inhibitors like phenolic compounds. The allelochemicals that are released

Table 1. Seasonal variation in soil nutrients concentration (30 cm depth) and soil moisture content (± SE) in the open grazing land (A) and the grazing land under *Albizzia* plantation (B).

Season	N (%)		P (%)		K (%)		Ca (%)		Mg (%)		Moisture (%)	
	A	B	A	B	A	B	A	B	A	B	A	B
Summer	0.065 ± 0.002	0.125 ± 0.006	0.007 ± 0.001	0.011 ± 0.001	0.069 ± 0.005	0.095 ± 0.001	0.014 ± 0.002	0.020 ± 0.0	0.007 ± 0.001	0.028 ± 0.001	3.2 ± 0.28	4.7 ± 0.30
Rainy	0.070 ± 0.002	0.103 ± 0.002	0.008 ± 0.001	0.013 ± 0.0	0.056 ± 0.003	0.11 ± 0.0	0.012 ± 0.001	0.017 ± 0.001	0.008 ± 0.0	0.014 ± 0.002	3.3 ± 0.61	3.8 ± 0.67
Winter	0.090 ± 0.001	0.128 ± 0.004	0.009 ± 0.0	0.013 ± 0.001	0.078 ± 0.002	0.122 ± 0.04	0.019 ± 0.002	0.032 ± 0.002	0.009 ± 0.0	0.032 ± 0.001	7.7 ± 0.35	9.2 ± 0.82

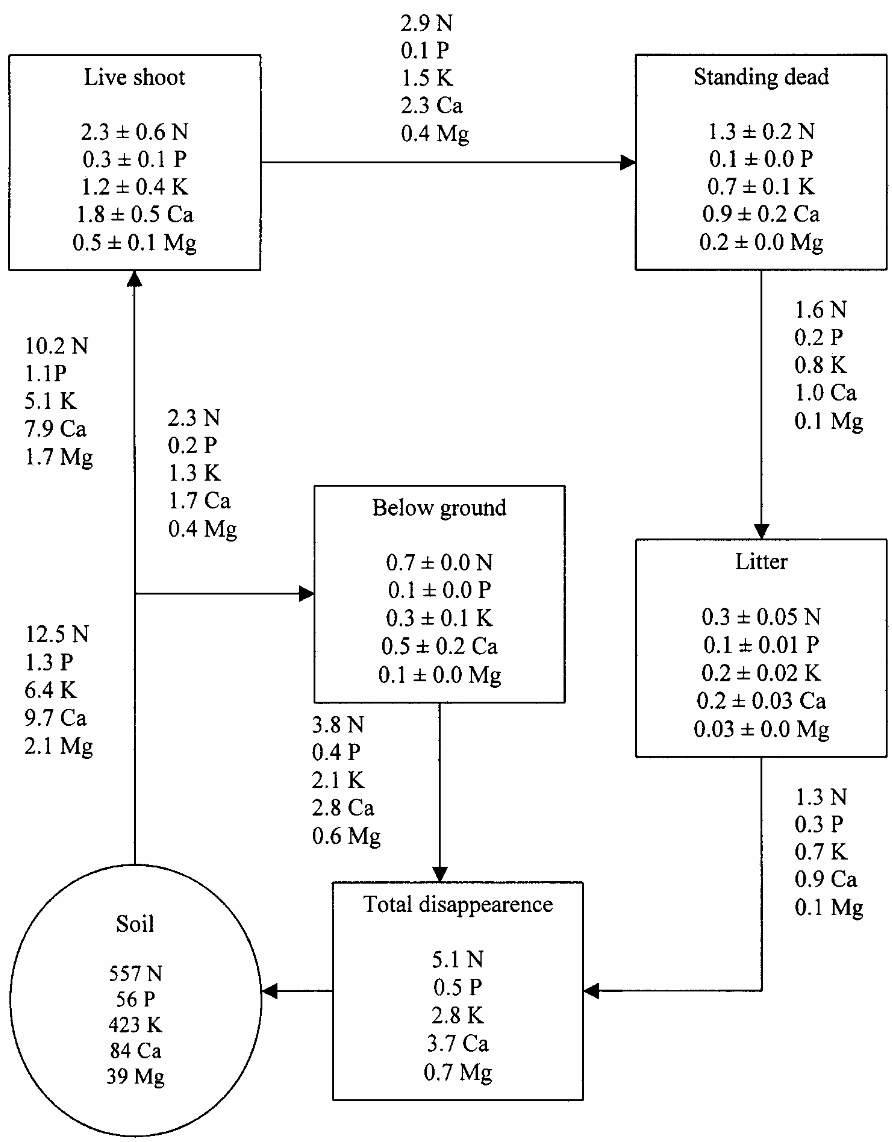

Fig. 4(a). Mean storage (g m^{-2}) and annual uptake, transfer and release (g m^{-2} yr^{-1}) of nutrients in the open grazingland. Values in compartments are storage and those on arrows are flux rates.

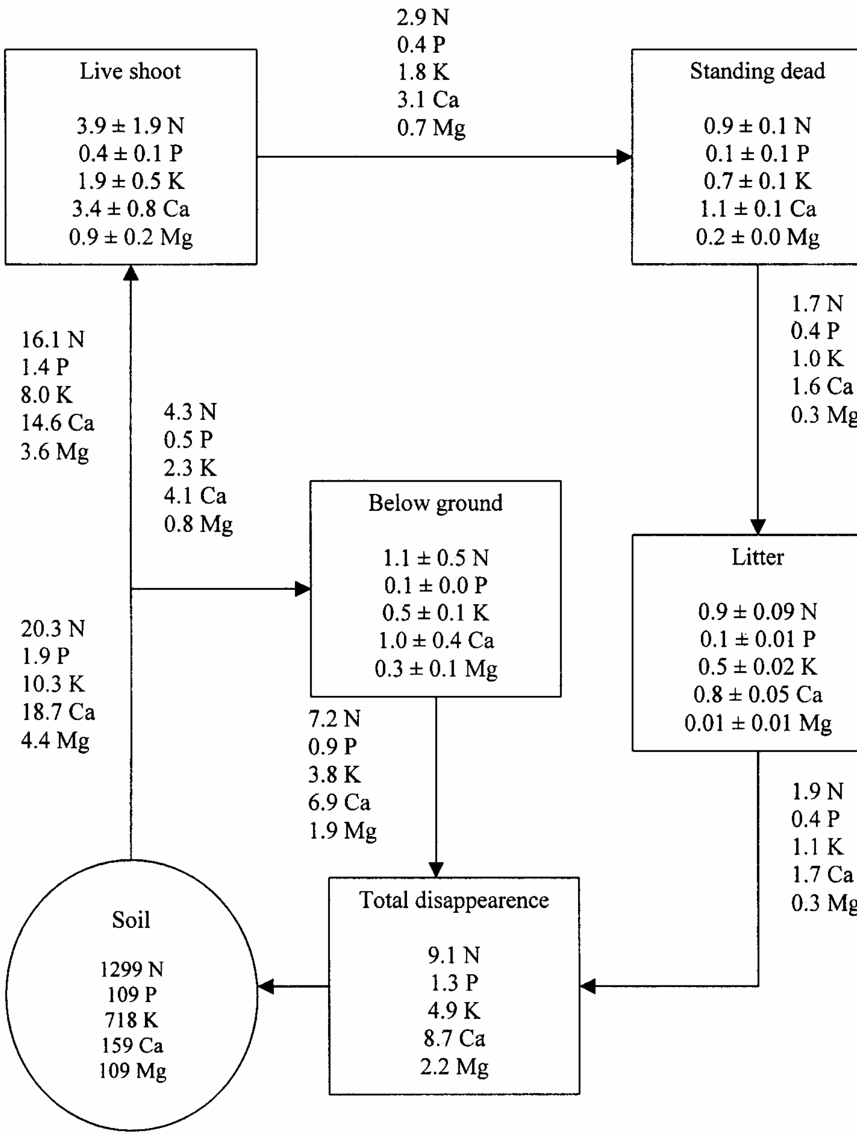

Fig. 4(b). Mean storage (g m^{-2}) and annual uptake, transfer and release (g m^{-2} yr^{-1}) of nutrients in the grassland under *Albizzia* plantation. Values in compartments are storage and those on arrows are flux rates.

through root exudates and leaf leachates in the *Eucalyptus* plantation reduces the NPP and nutrient content of the grazingland in the semi-arid region (Kailash Paliwal & Meenakshi Sundaravalli 1998). The selection of overstorey tree species can exert a significant influence on the subsequent plant growth. The present study reveals that the tree species such as *A. lebbeck* can increase the nutrient content of understorey grasses by their rapid leaf turnover and decomposition of nutrient rich litter, which can result in significant increase in soil fertility.

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