# The impact of long-term grazing on soil nutrients and carbon dynamics in Sabz Kou rangelands

**RAIESI GAHROOEE Fayez** (1), **ASADI Esmael** (2) **and MOHAMMADI Jahangard** (1)

(1) Soil Science Dept., Faculty of Agriculture, ShahreKord University, P.O. Box 115, ShahreKord, Iran
(2) Natural Resources Dept., Faculty of Agriculture, ShahreKord University, P.O. Box 115, ShahreKord, Iran

**Abstract**

In rangeland ecosystems, heavy grazing causes reduced input of aboveground litter to the soil. This may have important consequences for soil nutrient cycling and soil organic matter dynamics. Yet, the effect of grazing on soil nutrients and C dynamics in these ecosystems is not well-known. In this study, we evaluated soil nutrients and litter decomposition in two sites protected from grazing for 16-years in a semi-arid native rangeland (Sabz Kou region) in Central Iran. Soil sampling was performed to 15-cm depth in two adjacent non-grazed sites, and in one heavily grazed site at a distance of 3 km far away from the non-grazed sites. Aboveground litter decomposition of three dominant species (namely, *Agropyron intermedium, Hordeum bulbosum* and *Juncus* sp.) was studied using a litter bag experiment under field conditions.

The impact of grazing conditions on soil pH was significant, but inconsistent. Grazed and ungrazed practices were similar in their effect on soil bulk density. Soil C and total N concentrations did not vary between treatments, while extractable P and available K contents were higher at non-grazed sites. The C and N pools were similar for both grazed and non-grazed sites. The C/N ratio of soil was significantly higher at the grazed site. Grazing conditions had no significant effect on litter decomposition rate of all species. The three pasture species, however, showed significant differences in litter decomposition rate. Thus, 16-year protection from grazing by sheep had no considerable impact on C and N sequestration in soil as compared with grazed site, however, plant nutrients inputs may increase as a result of increased herbage production under grazing exclusion conditions. In summary, significant differences occurred in litter decomposition may potentially affect C dynamics more than rangeland management practices.

**Keywords:** nutrient cycling, decomposition rate, available K, extractable P, Sabz Kou rangelands

## Introduction

The natural semi-arid rangelands of Sabz Kou occupies about 35,000 ha in Central Iran. These rangeland ecosystems comprise an important and consistent source of herbage production for livestock feed. Feed shortages, particularly in unfertilized rangeland soils, always constrain livestock output in Sbaz Kou region. Continuous over-grazing, especially by sheep, is a common and frequent practice for livestock production in Sbaz Kou rangelands.

An extensive body of work has indicated that heavy grazing may directly affect soil physical, chemical and biological properties in different ways (Chaneton *et al*., 1996; Lavado *et al*., 1996; Berg *et al*., 1997; Dahlgren *et al*., 1997; Smit and Kooijman, 2001). Grazing may also have an indirect effect on soil characteristics through changes in plant species composition (Frank *et al*., 1995; Smit and Kooijman, 2001). Subsequently, nutrient cycling, pools and fluxes in rangelands subjected to long-term grazing may alter at the ecosystem level.

The most evident impact of grazing on rangeland ecosystems is removal of a major part of aboveground biomass by livestock (Shariff *et al*., 1994, Smit and Kooijman, 2001; Menezes *et al*., 2001). Therefore, the input of aboveground litter to the soil decreases. Any reduction in litter inputs may have important consequences for soil nutrient conservation and cycling (Shariff *et al*., 1994). Grazing decreased the input of nutrients in a grass-encroached Scots pine forest (Smit and Kooijman, 2001). Frank *et al*. (1995) showed that grazing intensity affected soil C and N contents of Northern Great Plains grasslands. Theirs results indicated that soil N and C contents were reduce by long-term grazing, but heavy grazing did not reduced soil C when compared to non-grazed mixed prairie sites. In contrast, Lavado *et al*. (1996) suggested that soil C and N contents were not affected by grazing conditions in upland rangelands, but the extractable P was lowered under grazing conditions. In California oak woodland, grazing had no significant effect on soil nutrient concentrations (Dahlgren *et al*., 1997).

To provide insight in the role of range management on soil nutrients, it is necessary to understand the impact of grazing on the rate of litter decomposition (Shariff *et al*., 1994). Litter decomposition has emerged as a very important component of the study of rangeland ecosystems, as it represents a crucial process in nutrients cycling, particularly nitrogen (Cook, 1984; Upadhyay and Singh, 1989; Couteaux *et al*., 1995). Range grazing has the potential to affect the rate of soil organic matter decomposition, and consequently C and N cycling in rangeland ecosystems (Shariff *et al*., 1994; Singh *et al*., 1991). Previous research has suggested that litter decomposition was strongly influenced by livestock grazing (Shariff *et al*., 1994; Singh *et al*., 1991). The moderate grazing increased litter decomposition and soil N mineralization rates, whereas no consistent differences were observed between the long-term ungrazed and heavily-grazed rangelands in Central North Dakota (Shariff *et al*., 1994). Singh *et al*. (1991) reported that plant residue decomposition was faster under grazing conditions than that under ungrazed conditions. In pastures of Wyoming, grazing increased $CO_2$ exchange rate over the whole season (LeCain *et al*., 2000). These impacts are likely due to dung and urine deposition by grazing livestock. As a result of grazing, increased decomposition rate may lead to enhanced nutrient availability, if other factors influencing decomposition remain unchanged. Thus, this would provide a positive feedback to plant growth and litter production.

The objective of this study was to evaluate impacts of long-term grazing practices on soil nutrient concentrations and litter decomposability in an area protected from grazing by sheep for 16 years in Sbaz Kou rangelands in Central Iran.

## Materials and Methods

### Research area

The study region is located near the village of Chahartag, approximately 130-km southeast of Shahre Kord in ChaharMahal Va Bakhtiari province, Iran, at an altitude of 3,000 m a.s.l. The annual rainfall is about 864 mm. The average yearly temperature is 6.7°C. The area (*ca* 1,000 ha) is a rolling forested region, sloping down to the south. The vegetation of the study location is representative of the major types of Zagrous mountains. The area is a typical, natural woodland-rangeland which is dominantly covered by pasture species composed of *Agropyron intermedium* (Host) P. Beauv*, Hordeum bulbosum* L*., Juncus* sp.*, Bromus tomentellus* Boiss*, Bromus tectorum* L*., Bromus danthonia* L*., Poa bulbosa* L. The upstory is dominated by a tree layer including *Acer Persicum*, *Farxinus* sp., *Crataegus azarolus* L. and shrubs such *as Daphne mucronata* Royle., *Astragalus adscendens* Boiss and ausskn., *Juniperus polycarpos* C. Koch. Soils of the area are calcareous, brown silty clay loam, derived from Tertiary marl.

### Site selection

We divided the study location into a grazed area (600 ha) which is over-grazed continuously by sheep (several centuries) with a variable stock rate, and ungrazed area (400 ha) which has not been subjected to sheep grazing since 1985. The herbage of most pasture species in the grazed area is removed by grazing sheep so that nothing is left behind except trees and shrubs. The ungrazed area, located in the middle of the grazed area, was fenced to exclude livestocks. On the basis of vegetation type, the ungrazed area was divided into tree-dominated (TD) and pasture-dominated (PD) sites, each with an area of about 10 ha (two 10-ha ungrazed sites). A geo-referenced ungrazed area with similar soil parent material, slope, soil hydrological conditions, and vegetation attributes selected as to exclude factors other than grazing conditions that may contribute to spatial variation of soil properties.

### Soil sampling and analysis

Soil sampling was carried out in May 2000 at the three sites to make an inventory of C, N, P and K contents as a function of grazing management and plant community, and other potentially important (slope and elevation) soil forming factors. Ninety soil samples were collected to 15-cm depth at each site. Soil samples were air-dried at room temperature for 3 weeks, and passed through a 2-mm sieve prior to laboratory analysis. Total organic carbon, total nitrogen, extractable P, available K were determined following procedures described in Page *et al*. (1991).

### Litter bag experiment

Aboveground litters from the most dominant pasture species, namely *Agropyron intermedium*, *Hordeum bulbosum* and *Juncus* sp., in the grazed and ungrazed areas were collected in May 2000. Since lack of significant differences in chemical composition, litter samples of the three sites were pooled to obtain large composite samples, representative for the whole area. The samples were air-dried for one month at room temperature, and mixed carefully, and then the moisture content upon drying at 70°C was determined. Field litter decomposition was assessed using litterbag technique (Wieder and Lang, 1982). Litterbags, each containing three grams of the air-dried shoot were prepared. The litter samples were placed into nylon net bags (20×18 cm; 1×1 mesh size). Thirty bags of each species were surfaced-buried at each ungrazed site and grazed site. Burial time was mid September 2000. Litterbags were retrieved from the field following 3,6,9 and 12 months of decomposition. This procedure generated a total of 216 litterbags (3 litter type×4 retrieval dates×6 replicates per retrieval×3 decomposition sites). Upon retrieval the litterbags were washed to remove any soil particles, oven-dried at 70 °C overnight and weighted for remaining mass.

**Statistical analysis**

We analyzed differences in soil pH, bulk density, texture, and nutrient contents data between grazed and ungrazed sites using one-way analysis of variance (ANOVA). The original data were either arcsine or ln-transformed for equal variance and normal distribution before analysis. Differences between litter decomposition rate at various sites were analyzed using two-way analysis of variance. Differences were considered significant only when p values were lower than 0.5, unless expressed otherwise. All statistical calculations were carried out using SigmaStat (Jandel Scientific, Germany).

## Results and Discussion

**Litter decomposability**

Litter decomposition was calculated as the fraction of the initial dry mass remaining after 3, 6, 9 and 12 months incubation under field conditions (Table 1).

**Table 1** Analysis of variance of results. Remaining mass (RM) for the leaf litter of three pasture species (AI=*Agropyron intermedium*, HB=*Hordeum bulbosum* and JU= *Juncus sp.*) incubated at grazed and ungrazed sites under field conditions. Values are means, and standard error of means are in parenthesis. Similar letters indicate no significant difference among plant species at each decomposition time at p<0.05.

| Decomposition time (month) | Source of variance | F | P | Species | RM (%) |
|---|---|---|---|---|---|
| **3** | Site | 1.29 | 0.292 | AI | 68 (0.95) b |
| | Species | 7.88 | 0.002 | HB | 78 (0.95) a |
| | Site ×Species | 2.91 | 0.040 | JU | 62 (0.95) b |
| **6** | Site | 2.13 | 0.143 | AI | 46 (1.75) a |
| | Species | 13.58 | 0.0002 | HB | 48 (1.75) a |
| | Site ×Species | 4.38 | 0.009 | JU | 36 (1.75) b |
| **9** | Site | 4.44 | 0.022 | AI | 38 (0.901) a |
| | Species | 1.77 | 0.190 | HB | 42 (0.901) a |
| | Site ×Species | 0.451 | 0.771 | JU | 35 (0.901) a |
| **12** | Site | 0.176 | 0.84 | AI | 31 (0.901) a |
| | Species | 14.98 | <0.0001 | HB | 28 (0.901) a |
| | Site ×Species | 9.46 | <0.0001 | JU | 17 (0.901) b |

Across all species, similar litter decomposition was observed in grazed and ungrazed sites after 3, 6 and 12 months field incubation (Table 1). The only significant effect of range management on litter decomposition was a higher decomposition rate at the pasture-dominated (PD) ungrazed site (p<0.05) after 9 months field incubation.

Additionally, the litter decomposition rate was similar for both tree-dominated (TD) ungrazed and grazed sites over the entire period of experiment (Figure 1). This study showed that rangeland grazing might not change the litter decomposability of different litter types under field conditions. In conjunction with this study, (Shariff *et al*., 1994) observed no consistent difference between the long-term ungrazed and heavy grazing conditions in central North Dakota. In contrast, these authors observed higher litter decomposition in the moderately grazed rangelands compared to the long-term ungrazed and heavily-grazed rangelands. Carbon and nitrogen losses from litterbags were similar for both grazed and ungrazed sites in elk winter ranges (Menezes *et al*., 2001). Conversely, plant residue decomposition was faster under grazing conditions than that under ungrazed conditions (Singh *et al*., 1991). Le Cain *et al*. (2000) found that grazing increased $CO_2$ exchange rate over the whole season in pastures of Wyoming. These impacts are likely due to dung and urine deposition by grazing livestock. Considering similar decomposition rates in ungrazed and grazed rangelands of Sabz Kou region, it is expected that an increase in litter input under ungrazed conditions would enhance C accumulation in the soil.

Analysis of variance indicated significant differences in litter decomposition due to the effects of litter species (litter type) and a significant interaction of litter type and range management (Table 1, Figure 1). The *Juncus* sp. and *Agropyron intermedium* leaf litters had similar decomposition rate after 3 months incubation. During this period, the *Hordeum bulbosum* litter decomposed slower than the *Juncus* sp. and *Agropyron intermedium* leaf litters. At the end of 12 months incubation, the litter decomposition of *Juncus* sp. was faster than those of *Agropyron intermedium* and *Hordeum bulbosum*. Average yearly decomposition rate was 83% for *Juncus* sp. litter compared to 70% for *Hordeum bulbosum* and *Agropyron intermedium* litters. All species at all sites lost more than 70 % of the initial weight during the September to April period (Table 1).

Although grazing conditions had no significant effect on litter decomposition, there were significant differences in litter decomposition between species. This suggests that differences in decomposition rates of different plant species are greater than direct impacts of grazing conditions on C dynamics. So, changes in plant species composition as a result of grazing may be more important than direct effects of grazing on soil C decomposition.

**Soil parameters and nutrients**

Range management had no significant effect on the soil bulk density (Table 2). So, the increased litter input observed at the ungrazed sites (data not shown) was not reflected in decreasing the soil bulk density. Soil pH showed a small difference between all the sites, but the averaged soil pH value was significantly different between the three sites ($p=0.0003$, Table 2). At the grazed PD site, soil pH was significantly higher than that for grazed and ungrazed TD sites.

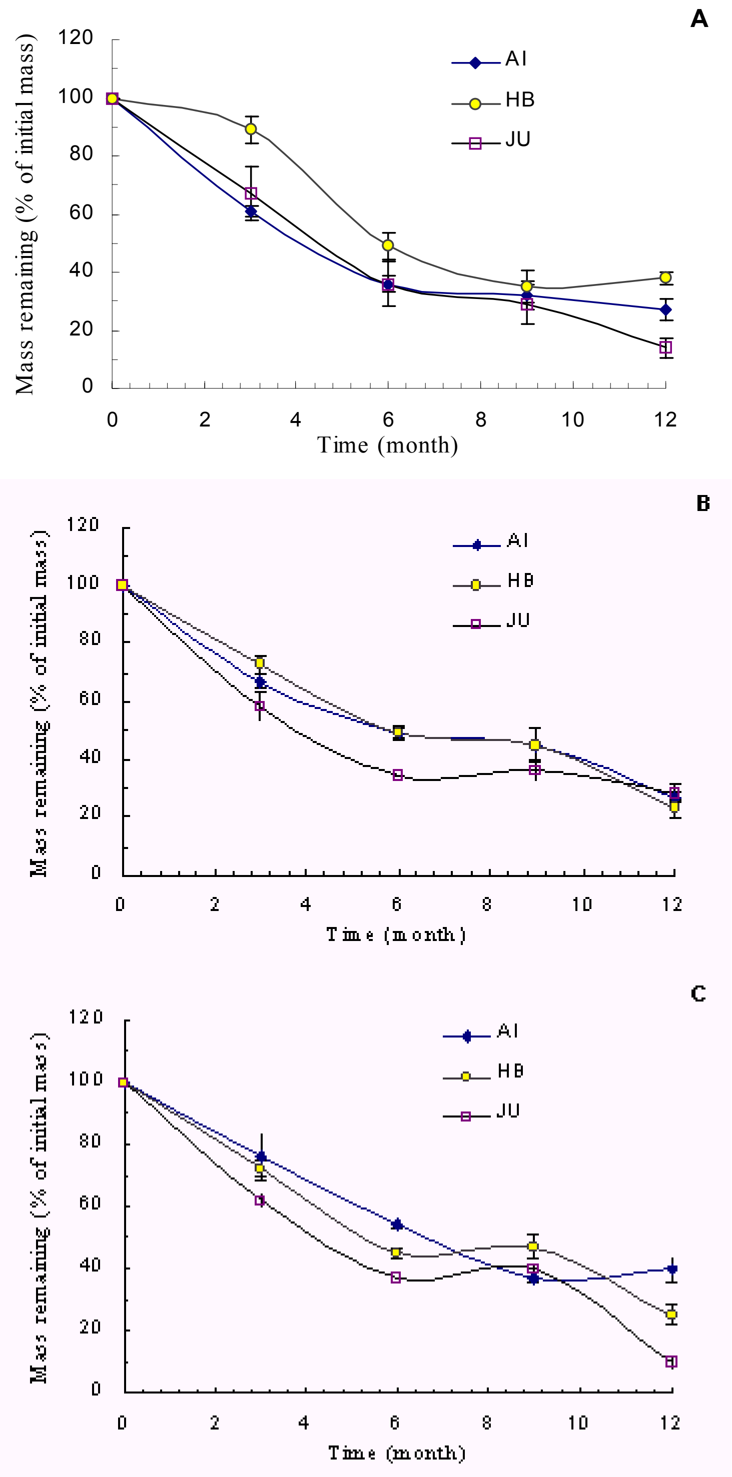


**Figure 1** Species-specific rates of decomposition for litter (AI=*Agropyron intermedium*, HB=*Hordeum Bulbosum* and JU= *Juncus sp.*) incubated at pasture-dominated (A), tree-dominated ungrazed (B) and over-grazed (C) sites following 3, 6,9 and 12 months of decomposition in the field.

**Table 2** The soil bulk density, pH, nutrient concentrations of 0-15 cm soil layer under different grazing conditions in Sabz Kou rangelands. Each value represents means (n=90), standard error of means are included in parenthesis. Similar letters indicate no significant difference among sites at p<0.05.

| Site | Bulk density (g $cm^{-3}$) | pH ($H_2O$) | C (%) | N (%) | K (cmol $kg^{-1}$) | P (mg $kg^{-1}$) |
|---|---|---|---|---|---|---|
| Grazed | 1.13 | 7.44 | 3.60 | 0.131 | 0.349 | 36.0 |
| | (0.027) | (0.035) b | (0.44) | (0.015) | (0.023) b | (1.48) c |
| Ungrazed PD | 1.10 | 7.58 | 3.72 | 0.153 | 0.876 | 77.1 |
| | (0.035) | (0.022) a | (0.38) | (0.011) | (0.091) a | (6.92) a |
| Ungrazed TD | 1.10 | 7.37 | 3.75 | 0.171 | 0.730 | 50.0 |
| | (0.031) | (0.031) c | (0.27) | (0.022) | (0.067) a | (4.55) b |
| F value | 0.270 | 11.7 | 0.047 | 1.40 | 16.7 | 18.5 |
| P value | 0.765 | 0.0003 | 0.950 | 0.260 | <0.0001 | <0.0001 |

Range management had no significant effect on the concentrations and pools of soil C (Tables 2 and 3). Similarly, soil N content and pool were not influenced by rangeland grazing. Grazing conditions had a significant impact on the extractable K. Soil K content was higher at both ungrazed sites. Grazing conditions had a significant effect on the soil P content. Soil P content was lower at the grazed site compared to ungrazed sites. The C/N and C/P ratios of soil were significantly higher at the grazed sites (Table 3). Under grazed conditions, the C/N ratio of soil was 22 % higher than that at the ungrazed sites.

**Table 3** C/N and C/P ratios and C and N pools of 0-15 cm soil layer under different grazing conditions in Sabz Kou rangelands. Each value represents means (n=90), standard error of means are included in parenthesis. Similar letters indicate no significant difference among sites at p<0.05.

| Site | C/N | C/P | C pool (kg $m^{-2}$) | N pool (kg $m^{-2}$) |
|---|---|---|---|---|
| Grazed | 34.7 (3.34) a | 1005(116) a | 6.10 (0.745) | 0.223 (0.026) |
| Ungrazed PD | 28.9 (3.59) b | 489(37) b | 6.13 (0.635) | 0.253 (0.018) |
| Ungrazed TD | 27.5 (2.08) b | 778(60) a | 6.20 (0.448) | 0.282 (0.037) |
| F value | 4.48 | 10.8 | 0.006 | 1.14 |
| P value | 0.012 | 0.00004 | 0.990 | 0.340 |

After 15 years protection from grazing, soil C was not significantly increased, indicating the decomposition rate of soil organic matter at the protected sites should be higher than that at the grazed site, if litter input to the soil is much higher at the ungrazed sites. We observed that litter decomposition was not affected by range grazing in this region. It, therefore, is expected that an increase in litter inputs should have led to the enhanced C content, if decomposition rate remains unchanged. Thus, unchanged C content of soil may be attributed to a higher decomposition rate of native carbon as a result of promoted biological activity due to roots, present at the ungrazed site. Also, the lower C/N ratio at the ungrazed site may indicate that the native soil organic matter decomposes more rapidly at this site.

The findings of this study are in agreement with results reported by Lavado *et al.* (1996) who found no impact of grazing on soil C and N contents in upland rangelands.

Also, the extractable P was lowered under grazing conditions. In California oak woodland, grazing had no significant effect on soil nutrient concentrations and C/N ratio (Dahlgren *et al*., 1997). Some other studies also showed little or no impact of grazing on soil nutrients. Berg *et al*. (1997) reported that soil C and N contents were not affected by grazing conditions in a sandy rangeland. Mapfumo *et al*. (2000) indicated that grazing had no consistent impact on soil parameters, and the grazing effect was minimal. In contrast, the input of nutrients in a grass-encroached Scots Pine forest was reduced by grazing (Smit and Kooijman, 2001). Frank *et al*. (1995) showed that grazing intensity affected soil C and N contents of Northern Great Plains grasslands. Theirs results indicated that soil N and C contents were reduced by long-term grazing, but heavy grazing did not reduced soil C when compared to non-grazed mixed prairie sites.

Overall, 16-years protection from grazing by sheep had no considerable impact on C and N sequestration in soil as compared with grazed site in Sabz Kou rangeland, however, plant nutrients inputs such as P and K may increase as a result of increased herbage production under grazing exclusion conditions.

## Conclusions

In this study, we compared soil nutrient contents and litter decomposition between grazed and ungrazed pastures. The results demonstrate that in the studied ecosystem, grazing conditions does not affect soil bulk density, soil C and N contents, pools of C and N, and litter decomposability. Our study indicates that as a result of herbage removal by sheep, soil P and K concentrations decreased under long-term grazing conditions. It was also evident that range grazing increased soil C/N ratio. The impact of grazing conditions on soil pH was not consistent.

Plant species has a significant impact on decomposition rate and nutrient cycling at ecosystem levels. We conclude that species composition has more influence on C cycling than grazing conditions so that effects of range grazing on species composition may impose an important feedback to soil organic matter dynamics.

We suggest that these data indicate different responses of soil nutrients and C dynamics to grazing is a reflection of different plant communities, environmental conditions and grazing management.

## Acknowledgements

The research reported in this paper was financed by the Research's Affairs Department of ShahreKord University.

## References

Berg, W.A., J.A. Bradford and P.L. Sims. 1997. Long-term soil nitrogen and vegetation change on sandhill rangeland. J. Range. Manage 50:482-486.

Chaneton, E.J. and R.S. Lavado. 1996. Soil nutrients and salinity after long-term grazing exclusion in a flooding Pampa grassland. J. Range. Manage. 49:182-187.

Cook, G.W. 1984. The application of soil science to increasing soil productivity. *In* J. Tinsley and J.F. Darbyshire (eds.). Biological Processes and Soil Fertility. Martinus Nijhoff/Dr W. Junk publishers, The Netherlands.

Couteaux, M.M., P. Bottner and B. Berg. 1995. Litter decomposition, climate and litter quality. Trends in Ecol. Evol. 10:63-66.

Dahlgren, R.A., M.J. Singer and X. Huang. 1997. Oak tree and grazing impacts on soil properties and nutrients in a California oak woodland. Biogeochemistry 39:45-64.

Frank, B., D.L. Tanaka, L. Hofmann and R.F. Follett. 1995. Soil carbon and nitrogen of northern great plains grasslands as influenced by long-term grazing. J. Range. Manage. 53:466-470.

Lavado, R.S., J.O. Sierra and P.N. Hashimoto. 1996. Impact of grazing on soil nutrients in a Pampa grassland. J. Range. Manage. 49:452-457.

LeCain, D.R, J.A. Morgan, G.E. Schuman, J.D. Reeder and R.H. Hart. 2000. Carbon exchange rate in grazed and ungrazed pastures of Wyoming. J. Range. Manage. 53:199-206.

Lupwayi, N.Z. and I. Haque 1998. Mineralization of N, P, K, Ca and Mg from sesbania and leucaena leaves varying in chemical composition. Soil Biol. Biochem. 30:337-343.

Mapfumo, E., D.S. Chanasyk, V.S. Baron and M.A. Naeth. 2000. Grazing impacts on selected soil parameters under short-term forage sequences. J. Range. Manage. 53:466-470.

Menezes, S.C., E.T. Elliott, D.W. Valentine and S.A. Williams. 2001. Carbon and nitrogen dynamics in elk winter ranges. J. Range. Manage. 54:400-408.

Page, A.L. 1991. Methods of Soil Analysis, Part2, Chemical and Microbiological Properties, 2nd. Amer. Soc. of Agro. and Soil Sci. Madison, Wisconsin. USA.

Shariff, A.R., M.E. Biondini and C.E. Grygiel. 1994. Grazing intensity effects on litter decomposition and soil nitrogen mineralization. J. Range. Manage. 47:444-449.

Singh, R.S., A.S. Raghubanshi and J.S. Singh 1991. Nitrogen mineralization in dry tropical savanna: effects of burning and grazing. Soil Biol. Bioch. 23:269-273.

Smit, A. and A.M. Kooijman. 2001. Impact of grazing on the input organic matter and nutrients to the soil in a grass-encroached Scots pine forest. Forest Ecol. Manage. 142:99-107.

Upadhyay, V.P. and J.S. Singh. 1989. Patterns of nutrient immobilization and release in decomposing forest litter in central Himalaya, India. J. Ecol. 77:127-146.

Wieder, R.K. and G.E. Lang. 1982. A critique of the analytical methods used in examining decomposition data obtained from litter bags. Ecology 63:1636-1642.