EFFECTS OF GRAZING, UTILISATION AND MANAGEMENT ON THE GRASSLANDS OF ROYAL BARDIA NATIONAL PARK, NEPAL

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
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CERTIFICATE

This is to certify that Mr. Jhamak Bahadur Karki of the Wildlife Institute of India has carried out original research titled "Effects of Grazing, Utilisation and Management on the Grasslands of Royal Bardia National Park, Nepal" in partial fulfilment of the M.Sc. (Wildlife Science) degree of Saurashtra University. These investigations were carried out under my supervision from November 1996 to June 1997. I also certify that this research has not been submitted for any other degree to any University.

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Dedicated to

My first teacher
Shree Bir Bahadur Dahal

SUMMARY

I studied the temporal effect of grass harvest, burning, fertiliser, and grazing, with a factorial experimental design, in three grasslands of Royal Bardia National Park, Nepal. I tested the hypothesis of (i) nutrient depletion of grasslands by continuous harvest and burning and (ii) differential use of areas by ungulates that were differentially managed in relation to forage quantity and quality.

Addition of Di-ammonium phosphate and urea did not result in a significant increase in green above ground biomass and forage quality. Cut-burnt plots had the highest nutrient quality as indexed by crude protein and lignin. Plots that were only harvested had highest above ground biomass for the first month following harvest, and were more intensively grazed by ungulates during that time. Ungulates preferred to graze cut-burnt and burnt areas more during the second and third month following the treatment. Unmanaged tall grassland areas were also observed to have nutritive and other wildlife values. A management strategy for the grasslands of Bardia based on the above results is suggested.

I compared the community structure, nutritive quality and above ground biomass of "grazing lawns" (patches of short grass communities), with neighbouring grasslands. Grazing lawns differed form neighbouring grasslands in species composition and community structure. A 50 day grazing free environment made areas of grazing lawns indistinguishable from neighbouring grasslands in terms of above ground biomass. Grazing lawns had more nutritive forage in terms of digestibility and crude protein content. Sodium, magnesium and phosphorus were found to be below the critical requirements of ungulates. These mineals were found in higher concentrations in forages from grazing lawns. Grazing lawns seem to be maintained by continuous grazing and enriched by deposition of urine, dung and by certain plant species not found elsewhere in the neighbouring grasslands.

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1. INTRODUCTION

The philosophy of management of natural resources varies from the most conservative concept "leave nature to take its own course" as in the case of Yellow-Stone National Park to "manage every square inch of area" as is the case of some European forests.

The management of Protected areas (PAs) in Nepal tends more towards the preservationist view in the mountains and manipulative form of management in the *terai*. The tropical and subtropical regions of Nepal had extensive forest cover until the recent past. The major chunk of these forests were destroyed after malaria was eradicated in the tropical and sub-tropical belt. This permitted the down-ward migration of the people from the mountains to the *terai* (south of Shivalik range) and may be the major reason responsible for destruction of the forests. The Royal Bardia National Park (RBNP), established in 1976, at present covers the largest chunk of forest within a single management unit (968 Km^2) in the *terai* region of Nepal. This is the largest PA of the Indo-Gangetic flood plain of India and Nepal. The Park management primarily caters to the conservation of biological diversity with an aim to strike a balance between anthropogenic use and wildlife values. None of the protected areas in the *terai* belt in Nepal are without human impact, albeit the magnitude varies. Most Grasslands of *terai* in Nepal have originated from anthropogenic activities (Jha 1992) and are quite recent (Singh and Gupta 1993). The major factors that are responsible for maintenance of the grassland successional stages are grass harvest, fire, grazing (wild and domestic ungulates) and in some areas, periodic flooding (Singh and Gupta 1993). Bardia is located on the alluvium of the Indo-Gangetic plain and grasslands are of savannah type (Frost and Robertson 1987). The present study sites on Royal Bardia National Park seem to be a outcome of earlier human intervention in the form of agriculture and grazing. The practice of burning, clearing of forests and grazing (by domestic cattle) were major form of human activities attributed to human use. These along with flood, erosion, siltation, natural fire, and complex environmental factors interacting with each other are likely responsible for creation and maintenance of these *"phantas"* (grasslands in local language). The practice of grass cutting in *terai* is carried out in dry season (Dinerstein 1979b; Mishra 1982; Lehmkul 1989). The Department of National Parks and Wildlife Conservation has permitted the local people to harvest grass from *terai* Parks and Wildlife Reserves (Lemhkul et al. 1988). Almost all remnant grasslands are now only found in protected areas and they are fulfilling the demand of the local people for thatch grass. Only about 13 percent of Nepal is under grassland (Annon 1992) and most of them now are confined to the area difficult to access. Therefore, grasslands of *terai* are important resources both for humans as well as wildlife.

After cutting most grasslands are burnt. Most grasslands would be burned by the Park management personnel. Since fire is a major force responsible for maintaining grasslands, the management practice of controlled burning contributes to maintaining this successional stage.

The removal of grasses for thatch and the practice of burning removes biomass as well as nutrients from the grassland ecosystem. There is a need to understand the effect of nutrient loss especially that of nitrogen and phosphorus form *terai* grasslands.

Grasslands of Royal Bardia National Park can be categorised as *Phragmites-Saccharum-Imperata* type (Dabadghao and Shankarnarayan 1973). Pokhrel (1993) has identified four association of grasslands; *Imperata-Narenga* type in upper Baghaura phanta;

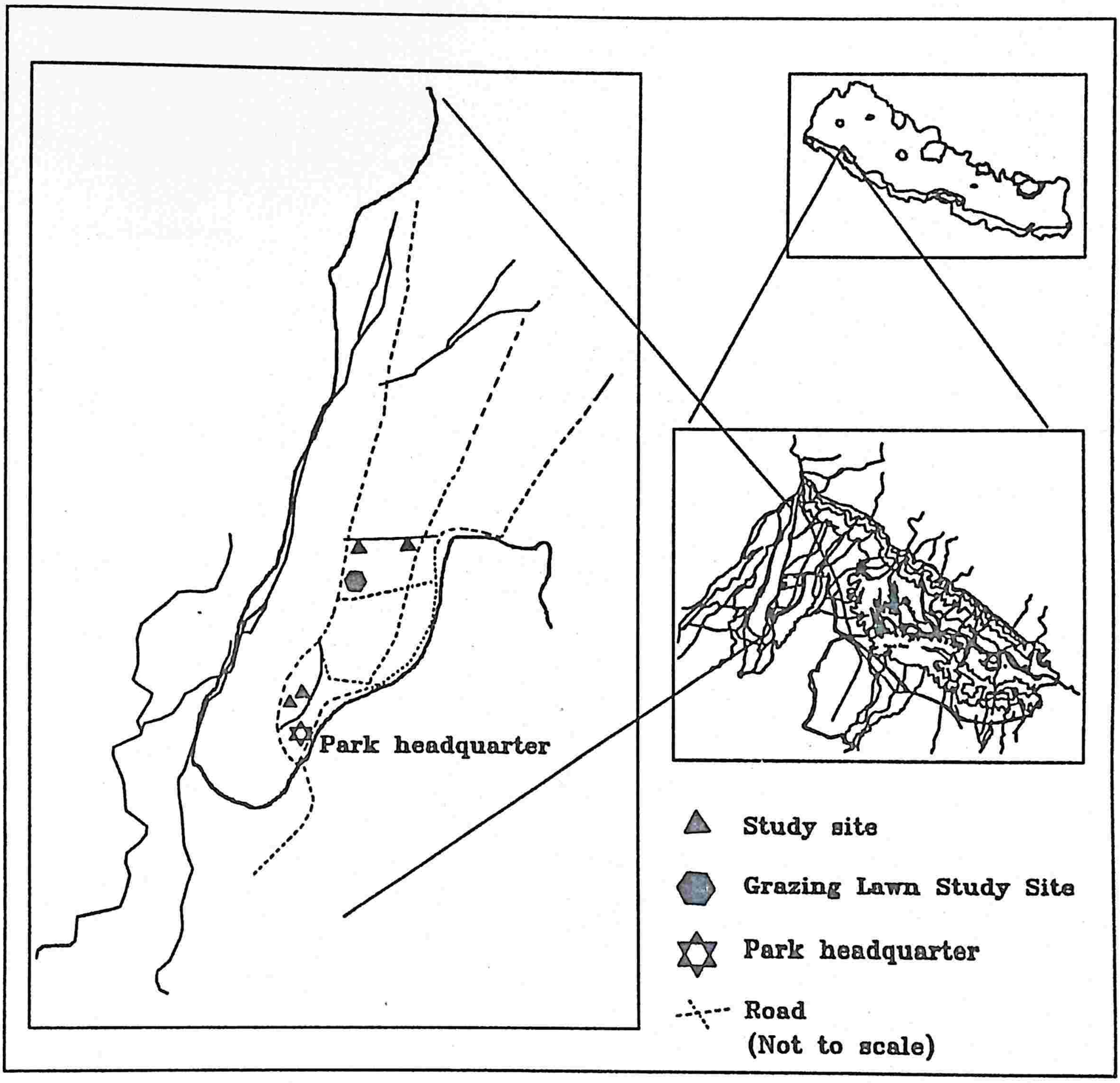
Imperata-Saccharum type in central Baghaura phanta; *Imperata-Desmostachya* type in upper Khauraha phanta; and *Imperata-Vetiveria* type in Lamkauli phanta.

Ungulates also dependent largely on grassland for their forage needs. During the dry season, the grassland becomes one of the major source of food for them. As grasses become tall and coarse, parts of the grassland with shorter grasses are more used by ungulates than the others. It is likely that continuous grazing in certain patches favours short phenotypes of the same species (McNaughton 1984). The mechanism and processes for formation and maintenance of such short grassland patches is not studied in the context of *terai*. Understanding of the effect of biomass removal and burning on grassland productivity and quality would be of use for formulating a management strategy for the grasslands in Bardia.

1.1. Study area

Royal Bardia National Park (RBNP) lies in the *terai* area of western Nepal (Figure 1). The park contains almost half of the Bardia district (968 Km^2). RBNP was established in 1969 as a Royal Hunting Reserve. In 1976, with an area of 348 $km^{2,}$ it was renamed as

Figure 1. Location of Study phantas in Royal Bardia National Park The map inset shows the location of the study site within Nepal



Royal Bardia Hunting reserve. In 1984 with the relocation of 1572 families, from Babai valley, the reserve was expanded to its present size. The reserve was upgraded to a National Park status in 1989.

1.1.1. Location

RBNP is situated about 585 km west of Kathmandu by road. RBNP is located (28° 15' to 28° 40'N and 80° 10' to 80° 50'E)' in the southwestern *terai* of Nepal. The study site, Baghaura phanta (28° 30.56'N 81° 15.15'E), Lamkauli phanta (28° 30.59'N 81° 16.69'E) and Khauraha phanta (28° 28.1'N 81° 14.70'E) are within 15 kilometre distance from Thakurdwara, the park headquarters. The Thakurdwara region is bounded by Geruwa branch of Karnali river in the west, village, agricultural field and Government forest in the south and east, and Churia ridge in the north.

1.1.2. Geology and soil

Physiographically the park has following distinct regions-Churia or Shivalik, *Bhabar* area, the alluvial flat land and the riverine floodplain. The study area lies in the riverine floodplain. This consists of coarse sand and fresh deposits of alluvial soil, silt and gravel.

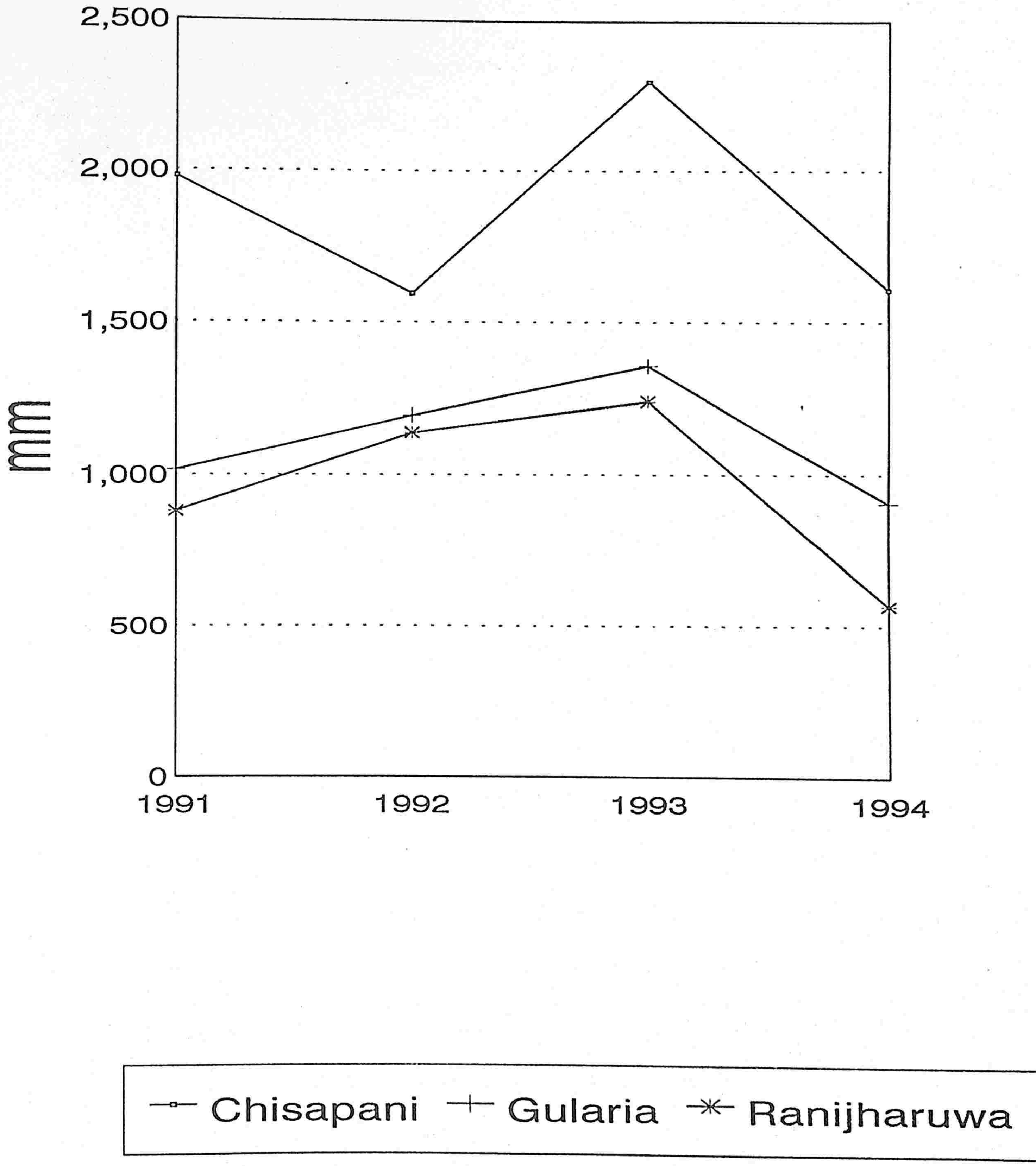
1.1.3. Climate

The climate is sub-tropical. The influence of monsoon is high and has three distinct seasons: hot dry season (Feb-mid June), Monsoon season (mid June-Late September) and winter season (late September-January). There is a distinct difference in the rainfall and temperature between these seasons. The dry season is hot and temperature reaches up to 40 ° C, rainy season receives more than two third of total annual rainfall (Figure 2) and cold season temperature drops down to 4-5°C. A strong northerly wind blows from the Karnali gorge and passes along the Karnali river which cools the area even in the hot season.

1.1.4. Vegetation

Champion and Seth (1968) have classified this forest as "moist semi-deciduous forest" in the *Bhabar*. Stainton (1972) supports this classification. The first study done for vegetation analysis (Dinerstein 1979a) classified the vegetation into six major vegetation types and this was modified to seven by Jnawali and Wegge (1993). These are 1. Sal forest 2. Khair-sissoo forest 3. Moist riverine forest 4. Mixed hardwood forest 5. Wooded grassland 6. Phanta and 7. Floodplain grassland. *Shorea robusta* is the dominant species in the "sal forest". More than two third of total vegetation is characterised as sal forest. Khair-sissoo forest is composed of *Dalbergia sissoo* and *Acacia catechu* and is confined to the water courses and floodplain islands. Moist riverine forest has more of evergreen species like *Syzizium cumini, Ficus racemosa,*

Figure 2. Rainfall of Karnali-Chisapani, Gularia and Ranijharuwa of Bardia district, Nepal.



Mallotus phillipinensis. Mixed hardwood forest has more shrub layer and open grown tree layer than riverine forest. *Garuga pinnata, Bombax ceiba, Adina cordifolia,* and *Mitragyna parviflora* are the major species. Phanta and wooded grassland are a result of earlier human disturbances. Wooded grassland are similar to savannah and open grasslands are called phanta. *Imperata cylindrica, Saccharum spontaneum* and *Vetiveria zizanioides* are common species in these grasslands. The floodplain has species like *Saccharum bengalensis, Phragmites karka* and *S.spontaneum* along the Karnali and Babai valley of RBNP.

1.1.5. Fauna

Dinerstein (1980) has listed 32 species of mammalian fauna in Karnali floodplain. The compilation done by Upreti (1994) lists 36 species but there are at least 39 mammalian species which are already recorded (Appendix 1). The latest additions are four-horned antelope (*Tetraceros quadricornis*), ratel or honey badger (*Mellivora capensis*), blackbuck (*Antilope cervicapra*) and fulvus fruit bat (*Rousettus leschenaultii*).

Inskipp (1989) provided a list of 261 species of birds but the number of bird species already identified are about 400 species (Pers. Comm. Khadka, J. B.). Herepeto-fauna and fish are among the least studied vertebrate fauna in Bardia. Aquatic fauna include mugger (*Crocodylus palustris*) and gharial crocodile (*Gavialis gangeticus*), otter (*Lutra perspicillata*), turtles, mahashir (*Tor putitora*) and other fish species. Twenty nine species of amphibians and three species of reptiles have been recorded till now (BPP 1996). Sixty species of fish have been recorded in Bardia (Maskey 1995).

2.6. Other Natural Features

The two perennial rivers, Karnali and Babai, are the major water source for wildlife as well as for people. Geruwa river (Eastern branch of Karnali river, known as Ghagra river in India) forms the western boundary of the park. It serves as the habitat for the last possible viable population of Gangetic dolphin (*Platanista gangetica)* in Nepal. The tributaries of both the rivers provide the edge which maintains the high bio-diversity of this park. A east-west highway traverse through the heart of the park. The Babai river has been dammed for Babai irrigation project.

1.2. Review of literature

Research in Bardia started since mid seventies, at a time when the Department of National Parks and Wildlife Conservation (DNPWC) came in to existence. The first landmark work was done by Eric Dinerstein who conducted an ecological survey of the Royal Karnali-Bardia Wildlife Reserve and its ungulate population (Dinerstein 1979a, 1979 b, and 1980). More research later was initiated by Norwegian Agriculture University (NORAGRIC), in collaboration with DNPWC, on ungulates and socio-economic aspects of villages around the Park.

Moe (1994) studied distribution and movement pattern of chital in response to food quality and manipulation of grassy habitats. He compared the nutritive quality of mature *Imperata cylindrica* with the new grass which grew after cutting and burning treatment. Chital were radio-collared for studying ranging patterns, habitat use and spacing behaviour. The mineral content and wildlife use of soil licks and aquatic vegetation were recorded to reveal alternative sources of minerals which was low in the grass forage.

Pokhrel (1993) studied floristic composition and biomass harvest in the Bardia grasslands. He found that biomass production varied among Baghaura, Lamkauli and Khauraha *phantas* from 10.27 to 13.98 t/ha. *Imperata cylindrica* was found to be dominant in all the three grasslands. About half of the biomass from the grassland was harvested from these three grasslands by locals during the grass cutting season and mean harvest rate was approximately 4 t/ha. Study focusing buffer zone management was carried by Bhatta (1993).

Stoen (1994) studied the status and food habits of tiger and estimated a minimum population of 8 tigers in Karnali floodplain. Three-fourth of the diet of tigers comprised of chital. Khatri (1993) studied the status and food habits of Nilgai (*Boselaphus tragocamelus*) and estimated their population to be 75-150 individuals in 8 sub-populations.

Pokhrel (1996) studied the food habits of barasingha (*Cervus duvauceli duvauceli*) during the winter season by direct observations and micro-histological study of the pellets and food plants. He found that the diet consisted of 82% grasses of which *Saccharum spontaneum*, *Imperata cylindrica* and *Themeda* spp. were most common. Ghimire (1996) studied the status and distribution of barasingha and estimated 73 individuals with a sex-ratio biased towards females (density 3.7 individuals/km^2).

Grazing affects species composition (Waston 1966) and species diversity (Edroma 1981). Fire has similar effect on species diversity and in combination with rain interacts to modify the grassland composition (McNaughton 1983). Species removal provided compensatory growth and resulted in different growth forms in different environments (McNaughton 1977).

Removal of grasses from an ecosystem is one of the major means of loss of nitrogen from the soil (Whyte et al., 1959) which can be compensated by a heavy dressing of nitrogen. In pure grasslands available nitrogen is limited, in the soil except in semi arid areas where soil moisture is deficient for higher productivity. Grass yield will be low in grazing lands in the absence of legume grass and if nitrogen fertiliser is not used. This may be comparable if ungulate biomass is high enough (Whyte et al. 1959) and replacement by less valuable species may occur in the grazing lands. The application of fertiliser may reverse the direction.

Alluvial soils (Nepal *terai*) are generally deficient in nitrogen and humus and sometimes in phosphorus. Potash is usually adequate. Lime content varies in tracts which are adjacent (Dabadghao and Shankaranarayan 1973). The mountain and hill soils provide nitrogen and organic matter which is subjected to leaching.

Herbivores have pronounced effect on plant establishment (Louda 1983); growth (McNaughton 1979b) and reproductive success (Janzen 1969). They also have substantial effects on plant forms (McNaughton 1976; 1979a; 1983). Among the most conspicuous effects of large mammalian grazers upon grasslands is a drastic reduction of above ground biomass and the activation of tillers that lead to a prostrate, dense canopy

(Vessey-Fetzgerald 1973; McNaughton 1976; 1979a; 1979b), referred to as GRAZING LAWNS (McNaughton 1984).

Grazing animals commonly adjust their densities and vegetation utilisation patterns in relation to the vegetation productivity potential, congregating and producing grazing lawns where that potential is high and dispersing from areas where that potential is low (McNaughton 1984). African ungulates in areas of moderate to high rainfall concentrate on small areas during the wet season and disperse into expanded ranges during dry season. In low rainfall areas, they commonly disperse over large areas during the wet season and congregate around the lake margins and in ground water-irrigated grasslands with a high productivity potential during the dry season (Lamprey 1963). These behavioural patterns tend to produce grazing lawns during periods of high utilisation and allow taller meadows to develop during periods of grassland disuse (Vessey-Fetzgerald 1969; 1973; 1974; McNaughton 1976; 1979).

Frequent, intensive grazing selects for prostrate, small leafed, and dwarfed ecotypes. There are often major differences in species composition and associated growth forms in vegetation. These are subject to different patterns of exploitation by herbivores since there are limits to natural selection for ecotypes tolerant of competition or grazing (Quinn and Miller 1967). Changes in species composition and growth form have been well documented (McNaughton 1979a, 1983), suggesting that growth form selection is a general consequence of grazing in diverse ecosystems.

Maintenance of grazing lawns increases the quality of food available to herbivores, particularly through enhanced nitrogen content (MaNaughton 1979b; McNaughton et al. 1982; McNaughton 1984). Grazing also increases the digestibility of forage (Olubajo et al. 1974) so that both nutrient content and relative yield to herbivores are greater in grazing lawns.

Quantitative characterisation of the effects of herbivory up on the structural characteristics of vegetation indicates that grazing lawns have a high plant biomass concentration (forage mass per unit volume) (McNaughton 1976, 1979a, 1979b) because of plant growth responses that pack productive, nutritious, and herbivore-sought tissues in to a small volume near the soil surface (Stobbs 1973, 1973b). The higher biomass concentration represents a potentially higher food yield to herbivores per mouthful eaten (Stobbs 1973, 1975; McNaughton 1976).

McNaughton (1984) tested the hypothesis and found that the area of high animal concentration had higher mineral content, especially magnesium, sodium and phosphorous.

Based on these studies which were done in Serengeti, I have tried to test similar hypothesis in the *terai* grasslands of Bardia. Moe (1994) had compared the nutrient content of mature *Imperata cylindrica* grass with fresh growth after the grassland were cut and subsequently burnt. Ungulates may not be able to select specific grasses for every bite rather they select areas for foraging at a macro level. Composite grass samples that are representative of the macro level selection were compared to test nutrient content differences of grasses in different treatments and patches.

In addition to forage quality, I investigated the response of above ground green biomass to various management treatments (cutting, burning, and cutting-burning). The difference in biomass productivity was compared between fenced and unfenced plots in each treatments.

1.3. Objectives

1. To study the effect of management on forage quality, above ground biomass and utilisation by herbivores in Bardia grasslands.
1. To try to understand the mechanism of formation and maintenance of grazing lawns.

1.4. Hypotheses

1.4.1. Hypothesis related to grass utilisation, management and grazing.

Most grasslands of Bardia are harvested annually by local people for use as thatch (Pokhrel 1993). It is a common practice to burn these harvested grasslands annually by the Park management. Such continuous removal of biomass by harvest and combustion are likely to be detrimental to grassland quality and may significantly deplete nutrients from the ecosystem. To evaluate the effect of grass harvesting, management burning on above ground production and their subsequent use by herbivores, the following research and statistical hypothesis were formulated;

1. The nutritive quality and above ground biomass of forage grasses was likely to respond differently to different management treatments like cutting, burning, and cutting-burning.

H0: Forage growing in areas of different management treatments of cutting, burning, and cutting- burning and different fertiliser treatments would have similar nutritive quality and above ground biomass.

2. Ungulates are likely to favour forages more in areas under certain management treatments compared to other areas.

H0: Grazing would reduce similar amounts of above ground biomass from areas under different management treatments.

1.4.2. Hypothesis related to grazing lawns

I speculate that short grass patches interspersed in the grasslands were established and maintained by continuous grazing by ungulates on these small patches compared to the remaining parts of the grassland and are similar to" grazing lawns" (McNaughton 1984). If this were true then several predictions follows

(A) Plant communities in herbaceous layer should differ between grazing lawns and neighbouring grassland in terms of species composition and ecotypes of the same species. Individuals of the same forage species should take on a more prostate - grazing adapted form (ecotypes) when compared to neighbouring grassland. This should result in shorter canopy height with higher forage volume.

(B) Underlying edaphic characteristics between grazing lawns and neighbouring grassland should be similar so as not to result in different plant communities.

(C) Grazing lawn should have forage with greater nutritive value and higher forage volume available to ungulate compared to neighbouring grassland.

The following statistical null hypothesis would test the above predictions:

Ho: Species composition and above ground biomass would not differ between the grazing lawns and neighbouring grasslands.

Ho: Edaphic characteristics are similar in grazing lawn and tall grassland.

Ho: Grass species in the same growth stage growing on grazing lawns and neighbouring grasslands have similar nutrient quality between grazing lawn and nearby tall grasslands.

2. METHODOLOGY

2.1. Grasslands

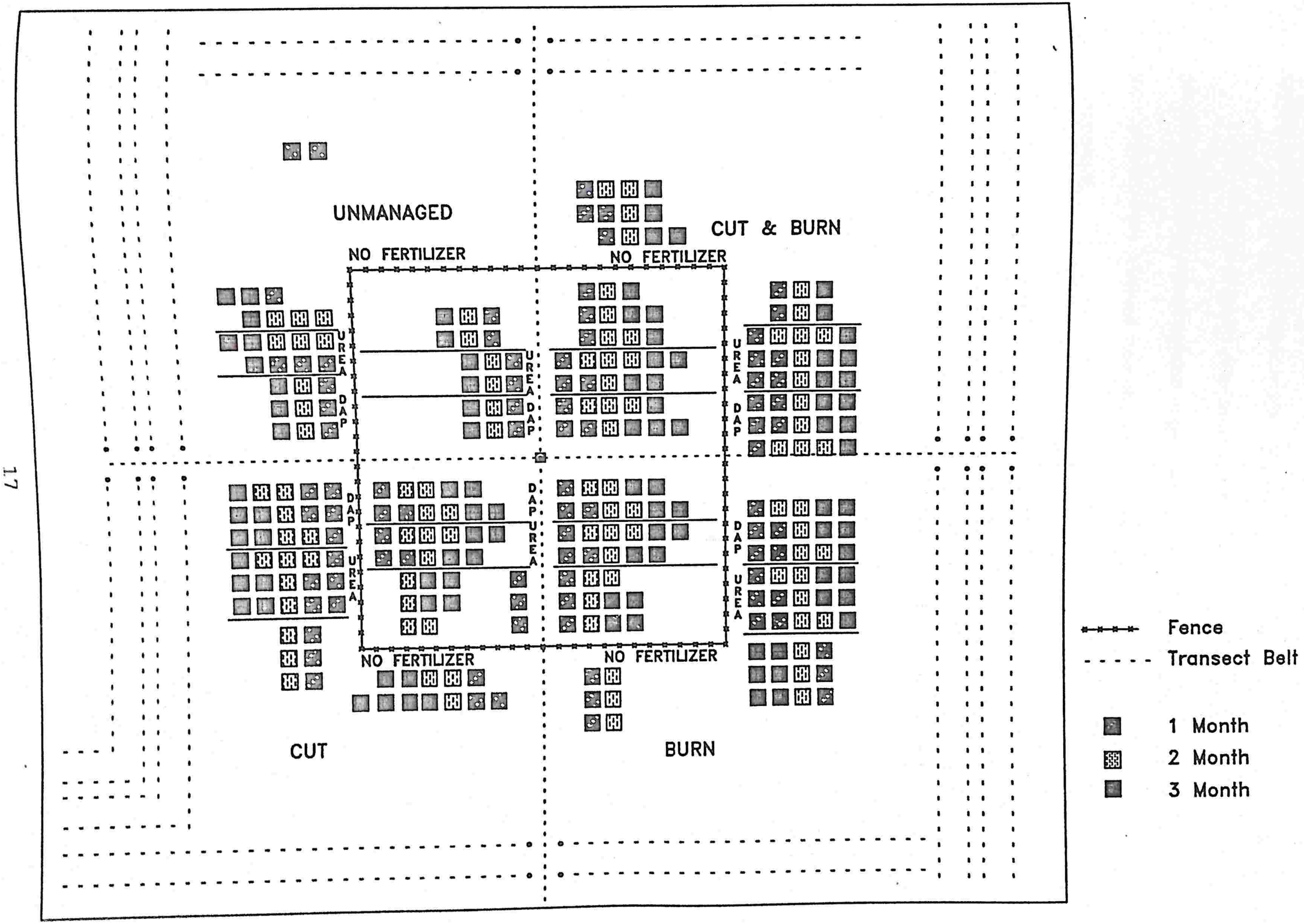
2.1.1. Research design

Three *phantas* (grasslands) (upper Baghaura, Lamkauli and upper Khauraha) were chosen for experimentation and biomass sampling to study the effect of grass biomass harvesting by villagers and burning practised as a management tool. Experimental plots were laid in the central portions of these *phantas*, where the grass communities were comparatively homogenous. Since the objective was to study the effect of cutting and burning and not quantify phyto-sociology, this selection reduced the inherent variability in species composition and biomass of the grassland that are associated with edge effects. In each grassland an area of about 5,000 square meters was chosen as a study site.

2.1.2. Grazing and Management treatment

A fence of 30 m x 25 m was constructed within the experimental plot of 50 m x 50 m blocks, in each *phanta* to prevent access by ungulates to grass biomass. The height of the fencing was 2 meter. Three management treatments, i) cutting (C), ii) burning (B), and iii) cutting followed by subsequent burning (CB), were applied to within and outside the fence (Figure 3). Grasses were cut at about 5-8 cm height from the ground.

Figure 3. Experimental design and location of quadrats



This was similar to the practice of general grass cutting done by locals during the grass cutting season which was same season when the experimental cutting was done.

The study plots which were surrounded by fire lines were burnt during late afternoon. Burning was completed in the same afternoon. In case of cut and cut-burnt area, grasses were removed from the plot prior to burning as was practised by the park management.

2.1.3. Fertiliser treatment

To understand the effects of biomass removal on quality and productivity, a long term study would be needed in the same area. Such a study design would be unfeasible with the constraint of time. The nutrients that are most likely to be depleted by continuous removal and burning of grasslands are nitrogen and phosphorus. I, therefore, treated areas within each management treatment with diammonium phosphate (DAP), urea and left an area untreated as control inside and outside the fencing. If, due to years of harvest and burning these elements were depleted in the system, then plant biomass should respond with greater growth in areas treated by these fertilisers. The areas treated with fertilisers inside the fence were i) 3 m x 15 m, ii) 3 m x 15 m and iii) 5.25 m x 15 m in size for the three treatments respectively. Di-Ammonium phosphate (DAP) was applied at 7.75 grams/m^2 to block i) and urea 3.9 grams/ m^2 to block ii). The third part was left without any fertiliser treatment as a control within each management treatment.

2.1.4. Sampling

Herbaceous biomass was sampled using a 1 m^2 quadrat at an interval of one month for three months following initial management and fertiliser treatment. Figure 3 summarises the experimental design and quadrats sampled within each treatment at a particular sampling interval.

Grass biomass was separated into two categories i) green biomass and ii) dead biomass. Fresh biomass of each species was determined in the field (up to 1 gram). Samples were then dried in air to get constant air dry weight. Improvised solar oven was used in the field to facilitate faster drying. The solar oven maintained a temperature between 50-70°C.

Other parameters recorded in the field from quadrat samples were percent cover, height, number of clump and tillers for each species of herbaceous vegetation.

Grass samples of all species occurring in quadrat samples were collected from all management treatments and fertiliser regimes for all 3 months from within the fenced area. These were sun dried in the field and brought to the laboratory, thoroughly dried and ground for further analysis.

Soil samples were collected from each grassland. They were collected from within the enclosure from the area of cut-burnt treatment. The upper 1-2 cm grass layer was cleaned. A 30 cm length by 30 cm breadth by 20 cm (deep) hole was dug. The soil was then thoroughly mixed. Fresh weight was taken in the field and packed in the paper bags for further analysis.

2.1.5. Animal signs using belt transects

Three 25 x 2 m belt transects were laid within each management treatment outside the enclosure. Individual ungulate pellets and pellet groups were identified by species and counted for each first, second and third months. After each sampling the transect was cleared of all faecal pellets.

2.2. Grazing lawns

To quantify the differences in species composition and forage quality between grazing lawns and surrounding grassland communities, 6 different grazing lawns were sampled within central Baghaura *phanta*. These grazing lawns were small areas with a maximum size of about 0.5 hectare. Six by six meter area of each grazing lawn was fenced by gabion wire to check grazing by ungulates. The height was 2 meter and was found to be successful in preventing entry of ungulates.

Six paired quadrats (50 cm x 25 cm) were clipped within each grazing lawn, enclosure within each grazing lawn and neighbouring grassland communities. Data were recorded on numbers, average height and biomass of herbaceous species.

To compare the available nutritive quality between forage species growing in the grazing lawn and in grassland communities, grass blades of dominant species such as *Imperata cylindrica*, *Saccharum spontaneum* and *Vetiveria zizanioides* in the same growth phase were hand plucked so as to simulate ungulate grazing. Fresh samples were weighted and sun dried prior to being brought to the laboratory for further drying and chemical analysis.

2.2.1. Soil

Two paired soil samples from each grazing lawn and corresponding grassland community area were collected. The soil was collected from a 30 cm width, 30 cm long and 20 cm deep pit. Once the upper 1-2 cm of root mixed layer is scalped, the remaining soil was mixed and a part of it used for laboratory analysis.

2.2.2. Belt transect

Four paired 10x2 m permanent belt transects were laid in each grazing lawns and tall grass community. Ungulate pellets were counted in the transects in December 1996, February 1997, April 1997 and May 1997. The pellets and pellet groups of ungulates were identified to species, and after each count the transects were cleared of pellets.

2.3. Nutrient analysis

The oven dried grass samples were ground in an aluminium grinder and sieved through 1 mm mesh. The proportional dry biomass contribution of herbaceous species in each sub treatment, grazing lawn and associated grassland was computed. A composite plant sample was prepared by adding dry ground individual plant samples in proportion to their occurrence in the plot. Crude protein (CP), acid detergent fibre (ADF), lignin and acid insoluble ash (AIA) content were determined for *Imperata cylindrica*, *Vetiveria zizaniodes* and *Saccharum spontaneum* and the composite sample (Van Soest 1963, Goering and Van Soest 1970). Within species samples from all quadrats were pooled within a treatment for this analysis.

Growing tips of the same species and composite sample from grazing lawn and nearby tall grass community were analysed for crude protein (CP), acid detergent fibre (ADF), lignin and acid insoluble ash (AIA), major element (Na, Ca, P, K, and Mg) and trace element (Fe, Cu and Mn, Zn).

2.4. Soil analysis

Soil samples were collected from each grazing lawn and corresponding tall grassland. Analysis for major elements such as Ca, P, Mg, Na, K and trace elements such as Fe, Cu and Mn were done for all soil samples.

Elements for grass and soil samples were analysed at WADIA Institute of Himalayan Geology, Dehradun by using Inductively Coupled Plasma-Atomic emission spectrometry (ICP_AES) (Potts 1987; Thompson and Walsh 1989). Na and K were analysed using a flame photometer. Soil samples were analysed against standard soil samples (GSS.I and GSS.4). Solutions were prepared for both grass and soil sample. Grass samples were analysed using salt standard. ICP_AES and Flame photometer was used for this analysis.

2.5. Statistical analysis

Data were first tested for normality using Kolmogorov-Smirnov non-parametric procedure and later analysed using procedures of Analysis of Variance (ANOVA) and Student's t-tests (Zar, 1984). Discriminant analysis procedure was used to differentiate quadrat samples of grazing lawns from grasslands based on herb layer community structure. The SPSS_PC (Norusis 1990) based software was used for all analysis.

3. RESULTS

3.1. Grassland-Management and grazing

3.1.1. Species composition of experimental phantas

All the three *phantas*; Baghaura, Lamkauli and Khauraha could be classified as *Imperata cylindrica, Vetiveria zizanioides* and *Saccharum spontaneum* grasslands as reported by Pokhrel (1993) and Moe (1997). However, the proportional contribution of these species to above ground plant biomass differed in the 3 grasslands (Table 1).

3.1.2. Soil Characteristics

Average moisture content and soluble nitrogen in the soil was higher in Khauraha compared to Lamkauli and Baghaura *phantas* (Table 2). Lamkauli phanta had lower amount of sodium, calcium and manganese than Baghaura and Khauraha *phantas.*

3.1.3. Temporal response of above ground biomass to management, fertiliser and grazing

First Month

Quadrat data from all 3 grasslands were pooled for a 3-way ANOVA design to understand the effect of management (cut, burn , cut-burn and no treatment); fertiliser (DAP, urea and no fertiliser) and grazing (fenced and unfenced) on above ground plant biomass (AGB). Three way interaction between management, fertiliser and grazing and all two way interaction terms were statistically non-significant while each of the treatments (main effects) altered AGB significantly (Table 3; Figure 4).

Table-1. Percentage of dry biomass species in three *phantas* of Royal Bardia National Park, Nepal.

Species	Baghaura	Khauraha	Lamkauli
Imperata cylindrica	26.68	75.15	51.6
Saccharum spontaneum	40.42	14.87	0.16
Vetiveria zizanioides	14.54	2.42	38
Saccharum narenga	16.12	1.93	0.69
Bothrichloa spp.	2.05	0.6	6.22
Fimbristylis spp.	0.17	0	0
Desmostachya bipinnata	0	5.03	0

Table 2. Comparison of mineral contents (ppm) and other characteristics of soil sample from Baghaura, Lamkauli and Khauraha *phantas* in Royal Bardia National Park, Nepal.

Parametrs	Baghaura	Khauraha	Lamkauli
P_2O_5	0.22	0.2	0.166
MnO	0.072	0.068	0.025
Fe_2O_3	5.22	5.19	4.25
CaO	2.86	2.67	0.37
MgO	2.91	2.67	1.16
Cu	34	30	21
Na_2O	1.26	1.31	0.51
K_2O	3.34	3.11	2.82
Soluble nitrogen	2.89	4.29	2.71
pH	9	9	9.5
Moisture content	10.25	28.15	9.44

Table-3. Temporal influence of management, grazing and fertiliser treatments on Above Ground Biomass on three experimental *phantas* in RBNP, in a full factorial ANOVA design.

S	Month 1			Month 2			Month 3		
	F	Df	P	F	Df	P	F	Df	P
Ft	5.87	2,23	0.03	1.84	2,23	0.16	15.2	2,23	0.00
Fn	15.2	1,23	0.00	22.3	1,23	0.00	5.42	1,23	0.02
M	69.3	2,23	0.00	16.5	2,23	0.00	15.3	2,23	0.00
Fn*F	0.02	2,23	0.99	0.67	2,23	0.51	1.07	2,23	0.34
Fn*M	0.34	4,23	0.85	2.59	2,23	0.08	0.25	2,23	0.78
Ft*M	1.61	2,23	0.20	0.47	4,23	0.76	2.62	4,23	0.04
Ft*Fn*M	0.15	4,23	0.96	0.49	4,23	0.75	0.12	4,23	0.97

Ft= Fertiliser; Fn=Fencing; M=Management ; Df= Degree of freedom (numerator, denominator); S =Source of variation.

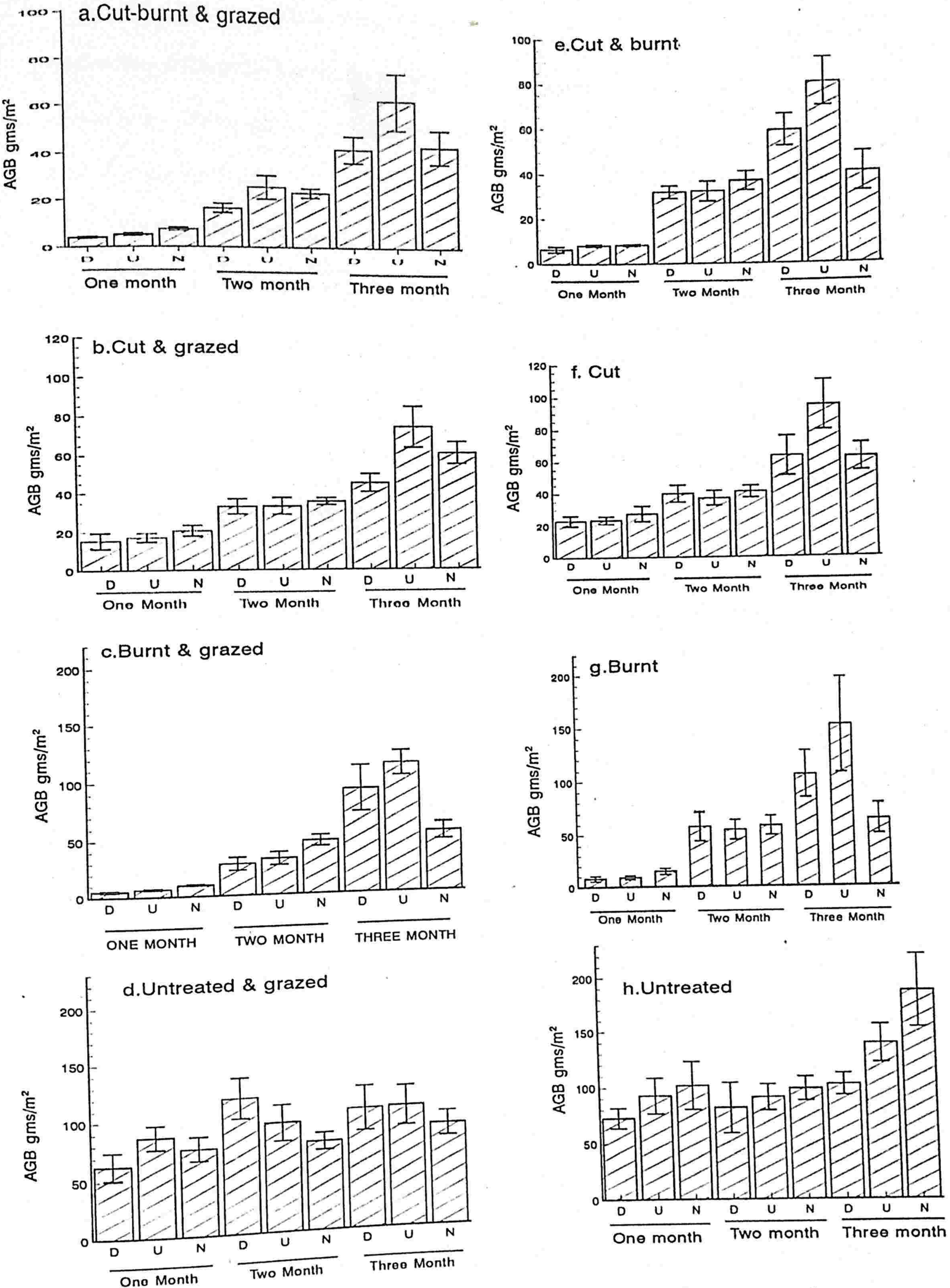


Figure 4: Temporal response of above ground biomass of grasslands to management treatments, grazing and application of DAP(D), Urea (U) and no fertilzer(N)

The ANOVA result suggests that during the first month the AGB was not responding differently between various levels of treatments to fertiliser and grazing (no interactions). However, the management (Mt) treatment, fertiliser (Ft) and grazing (Fn) were altering AGB individually.

Similar ANOVAs were performed on data from individual grasslands. In Baghaura and Khauraha *phanta* the pattern conformed to the overall ANOVA showing no significant interactions while in Lamkauli *phanta* there were a significant interactions between management treatment and fertiliser and management treatment and grazing (Table 4, figure 5). In Baghaura, fertiliser and grazing did not alter AGB during the first month while all main effects (management, fertiliser and grazing) altered AGB for Lamkauli and Khauraha *phantas* (Table 4; figure 5).

To investigate how each of these treatments was affecting AGB individually, separate 1-way-ANOVAs followed by multiple range tests were done for each grassland keeping two of the treatment levels constant; for example, testing for effect of cutting within the fence for all plots treated with urea. This analysis suggests that AGB production was higher for the areas that were cut. There was a tendency (not statistically significant for all grasslands), for cut-burn plots to be more heavily grazed. There was no consistent pattern of AGB response to fertiliser treatments.

Table 4. Influence of management, grazing and fertiliser treatments on above ground biomass on 3 experimental *phantas* in RBNP, in a full factorial ANOVA design after 1 month of treatment.

S	Baghaura			Lamkauli			Khauraha		
	F	Df	P	F	Df	P	F	Df	P
Ft	1.72	2,57	0.19	92.36	2,57	0.00	4.11	2,57	0.02
Fn	1.12	1,57	0.29	38.56	1,57	0.00	8.97	2,57	0.004
M	72.4	2,57	0.00	159.5	2,57	0.00	14.82	2,57	0.000
Fn*Ft	0.68	2,57	0.51	2.053	2,57	0.14	0.07	2,57	0.934
Fn*M	0.50	2,57	0.61	18.91	2,57	0.00	0.216	2,57	0.807
Ft*M	0.93	4,57	0.46	14.54	4,57	0.00	1.65	4,57	0.172
Ft*Fn*M	1.11	4,57	0.36	1.01	4,57	0.41	0.132	4,57	0.97

Df=Degree of freedom (numerator, denominator); S=source of variation; Ft= Fertiliser; Fn=Fencing, M=Management

Response of above ground biomass to management, grazing and fertilizer treatments

Figure 5 One month

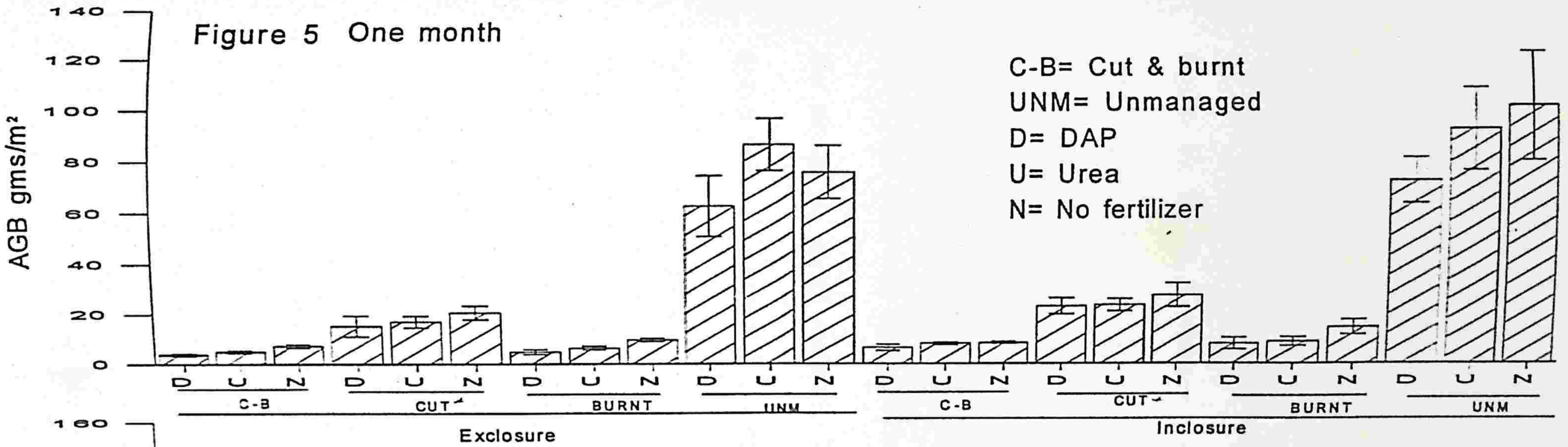


Figure 6 Two month

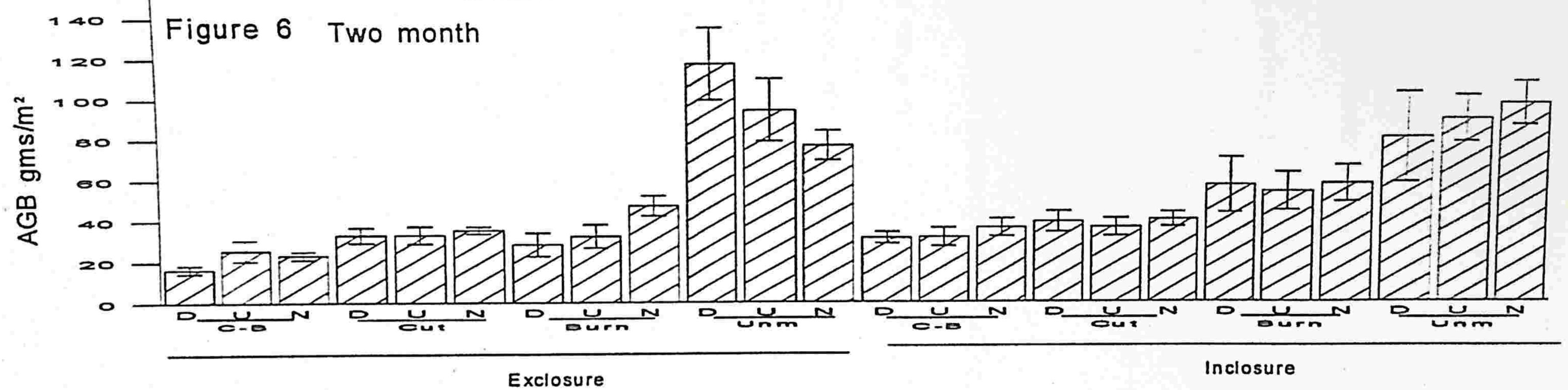
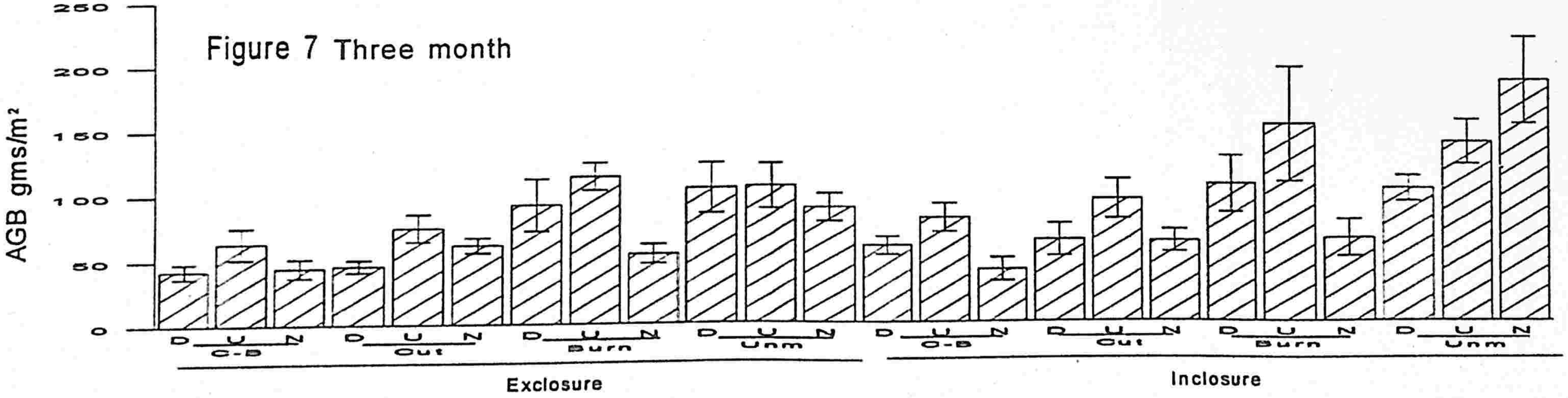


Figure 7 Three month



Second Month

For the pooled quadrat data of all 3 grasslands for the second month, three-way interaction between management, fertiliser and grazing and all two-way interaction terms were statistically non significant. Management and grazing treatments (main effects) individually altered AGB during the second month (Table 3; figure 4). There was no detectable changes in AGB for plots under different fertiliser treatments.

Similar ANOVAs were performed on data from individual grasslands (Table 5; figure 6). In all 3 *phantas* the pattern conformed to the overall ANOVA showing no significant 3 way interactions. All three grasslands responded differently to AGB in 2 way interactions (Table 5; figure 6).

To investigate how each of these treatments were affecting AGB, separate one way ANOVAs followed by multiple range tests were done for each grassland keeping two of the treatment levels constant. There was a mixed response for AGB production in the 3 grasslands as suggested by this analysis; in Baghaura *phanta*, cut plots were higher in AGB. Grazing and fertiliser showed no consistent pattern. Lamkauli *phanta* responded with higher AGB production from cut-burnt plots that also tended to be more grazed. AGB was low in DAP treated plots when compared with urea treatments and areas with no treatment in this *phanta*. Khauraha phanta showed higher AGB production consistently from burn plot but there was no consistent pattern from effects of grazing or fertiliser treatment.

Table 5. Temporal Influence of management, grazing and fertiliser treatments on above ground biomass on 3 experimental *phantas* in RBNP, in a full factorial ANOVA design following 2 months of treatment.

S	Baghaura			Lamkauli			Khauraha		
	F	Df	P	F	Df	P	F	Df	P
Ft	29	2,66	0.00	67.9	2,66	0.00	4.07	2,66	0.02
Fn	15	1,66	0.00	4.73	1,66	0.03	74.4	1,66	0.00
M	47	2,66	0.00	1.79	2,66	0.17	86.1	2,66	0.00
Fn*F	3.2	2,66	0.05	0.72	2,66	0.49	2.86	2,66	0.06
Fn*M	9.5	2,66	0.00	7.24	2,66	0.00	0.57	4,66	0.68
Ft*M	4	4,66	0.00	5.64	4,66	0.00	4.97	2,66	0.01
Ft*Fn*M	1.3	4,66	0.26	2.28	4,66	2.87	1.56	4,66	0.19

Df=Degree of freedom (numerator, denominator); S=source of variation;. Ft= Fertiliser; Fn=Fencing, M=Management

Third Month

Three way interaction between management, fertiliser and grazing and all two way interaction terms were statistically non significant except for management and fertiliser treatment. The grazing treatment (main effects) was significant (Table 3; figure 4). Since 2-way interaction term was significant for fertiliser and management, further inferences for these 2 treatments for main effects was not possible. However, grazing was reducing AGB significantly by third month.

Similar ANOVAs were performed on data from individual grasslands. Three way interactions between management, fertiliser and fencing (grazing) were significant ($p<.01$) in all 3 individual grasslands for AGB. Though the individual grasslands were significant for 3-way and 2-way interactions, the interactions were acting differently for different management and fertiliser treatments, thus overall significance was lost by combining these three grasslands.

To investigate how each of these treatments was affecting AGB, separate one way ANOVAs followed by multiple range tests were done for each grassland keeping two of the treatment levels constant. In Baghaura, cut treatment had greater AGB in comparison to Cut-Burn. Results suggest that AGB from cut-burn and burn treatments were responding similarly while both treatments differed in AGB with Cut plots. In case of Khauraha *phanta*, burn treatment was responding with higher AGB. Results suggest that cut-burn treatment tends to have lower AGB but the pattern was not consistent and was not statistically different from cut. In case of Lamkauli *phanta*, a specific pattern does not emerge for any treatments (Table 6; figure 7).

Table 6. Influence of management, grazing and fertiliser treatments on above ground biomass on 3 experimental *phantas* in RBNP, in a full factorial ANOVA design following 3 month of treatments.

S	Baghaura			Lamkauli			Khauraha		
	F	Df	P	F	Df	P	F	Df	P
Ft	4.73	2,66	0.01	91.1	2,66	0.00	77.6	2,66	0.0
Fn	23.9	1,66	0.00	1.20	1,66	0.28	19.5	1,66	0.0
M	7.21	2,66	0.00	0.31	2,66	0.73	88.7	2,66	0.0
Ft*Fn	14.9	2,66	0.00	4.13	2,66	0.03	10.9	2,66	0.0
Fn*M	0.13	2,66	0.88	0.57	2,66	0.57	1.68	2,66	0.2
Ft*M	0.74	4,66	0.57	3.93	4,66	0.01	24.6	4,66	0.0
Ft*Fn*M	8.04	4,66	0.00	5.73	4,66	0.00	6.61	4,66	0.0

Df=Degree of freedom (numerator, denominator); S =source of variation; F= Fertiliser; Fn=Fencing, M=Management

3.1.4. Effect of fencing following management and fertiliser treatments

Above ground biomaas inside the fence and outside the fence was averaged for each fertiliser treatment under each management treatment in all 3 *phantas* separately. After pairing the averaged above ground biomass within and outside the fence by fertiliser within each management treatment, data were analysed by means of a paired t-test for each month separately.

Grazing reduced the green above ground biomass for the first 2 months following treatment (Month-1 t=2.78, df=23, p=0.11; Month-2 t=2.02, df=35, p=0.05). By the end of the third month there was no detectable impact of grazing (t=0.97, df=35, p=0.35).

3.1.5. Response of forage quality of composite sample

Nutrient analysis were done for a pooled sample of composite forage from each fertiliser treatment for all 3 *phantas* for each month within the fence (Table 7).

First Month

Two way interaction term between management and fertiliser was non significant for all four nutrients. Since interaction terms and main effects of fertiliser treatment of the 2 way ANOVA model were non significant, the model was collapsed to a one way ANOVA to investigate how nutrients were responding to management treatments.

During the first month the overall grassland response was an increase in crude protein (CP) for cut-burn management treatment (2-way ANOVA F=28.03, df=2,24, p=.001 followed by the 1-way ANOVA and multiple range test). Similarly, the overall grassland response was a higher content of acid detergent fibre (ADF) for cut management treatment (2-way ANOVA F=5.98; df=2,24 ; p=.0078 followed by 1-way ANOVA and multiple range test).

Table 7. Mean nutritive values CP (crude protein), ADF (acid detergent fibre), L (lignin) and AIA (acid insoluble ash) of composite sample for Baghaura, Lamkauli and Khauraha phanta in Royal Bardia National Park, Nepal.

Month 1		%CP	%ADF	%L	%AIA
Burn	Mean	13.165	38.623	7.0177	3.14
	SE	0.609	1.3635	1.2331	0.5214
C-B	Mean	16.06	37.441	9.0844	3.6659
	SE	0.6435	1.0059	0.948	0.6482
Cut	Mean	7.6058	42.836	9.666	3.3283
	SE	0.9858	0.8479	0.959	0.1758
Unm	Mean	6.0277	46.616	9.9073	3.6604
	SE	1.9379	1.2695	0.3962	0.2415
Month 2					
Burn	Mean	9.7057	38.369	10.05	4.3469
	SE	0.4491	0.3503	2.0909	0.2887
C-B	Mean	10.86	38.312	7.3227	4.6802
	SE	0.2975	0.6979	1.1038	0.3832
Cut	Mean	8.4917	42.021	9.6498	3.8721
	SE	0.3973	0.4467	1.5465	0.2271
Unm	Mean	3.7298	46.431	11.858	4.8336
	SE	0.2825	0.4093	1.3456	0.24
Month 3					
Burn	Mean	6.9046	42.395	8.5046	4.524
	SE	0.3715	0.7006	1.0517	0.278
C-B	Mean	8.0557	41.091	7.5711	4.8592
	SE	0.425	0.8029	1.144	0.2944
Cut	Mean	6.2598	43.145	8.8955	4.6368
	SE	0.1929	0.5113	1.2726	0.2386
Unm	Mean	4.7497	47.684	10.209	5.3411
	SE	0.2909	0.7405	0.8511	0.1747

C-B= Cut-Burnt treatment; Unm= Unmanaged treatment; SE= Standard error

Second Month

By the second month only CP (2 way ANOVA F=7.62; df=2,18; p=.004) and ADF (2 way ANOVA F=12.91, df=2, 18 ; p<0.000) differed within management treatments. Two way interaction term between management and fertiliser was non significant for all 4 nutrients.

Since interaction terms and main effects of fertiliser treatment of the 2 way ANOVA model were non significant, the model was collapsed to a one way ANOVA to investigate how nutrients were responding to management treatments.

This analysis suggested that CP was higher in cut-burn (1 Way ANOVA F= 8.35; df= 2,24; p=.0018) than cut and burn treatments and cut plots were having lower CP value. CP content of grasses were similar from burnt areas & cut areas. ADF was higher in forage from the cut treatment (1 Way ANOVA F= 14.89; df= 2,24; p=.0001).

Third Month

By the third month only CP (2 way ANOVA F=5.55; df=2, 18; p=.013) differed within management treatments. Two way interaction term between management and fertiliser was non significant for all 4 nutrients.

Since interaction terms and main effects of fertiliser treatment of the 2 way ANOVA model were non significant, the model was collapsed to a one way ANOVA to investigate how nutrients were responding to management treatments.

This analysis suggested that CP content was higher in the cut-burn plots (1 Way ANOVA F= 6.2; df= 2, 24; p=.0067) in comparison to cut & burn plots. The trend of cut plots having lower CP value was consistent in third month also. Response was similar from burn & cut treatment to second and first month. Though ADF was not statistically different between management treatments, cut areas had higher ADF compared to the burn and cut-burn treatments. ADF was lowest in case of cut-burn plots, similar to that observed for first and second months.

3.1.6. Comparison of nutrient content of dominant species from all three phantas with respect to treatments after two months

Two-way ANOVA results showed that interaction between management and fertiliser treatments were non significant for all 4 nutrients. Management treatment (main effect) was significant for CP in all 3 species, *Imperata cylindrica* (2-way ANOVA F=9.04; df=2, 18; p=.002); *Saccharum spontaneum* (2-way ANOVA F=14.08, df=2, 8, p=.002) and *Vetiveria zizanioides* (2-way ANOVA F=18.69, df=2, 13, p<0.001). Only ADF content of *Saccharum spontaneum* differed between management treatments (2 way ANOVA F=10.53, df=2, 8; p=.006) from this pooled sample during second month. AIA and lignin content did not differ between management or fertiliser treatment for any species.

Since interaction terms and main effects of fertiliser treatment of the 2 way ANOVA model were non significant, the model was collapsed to a one way ANOVA to investigate how nutrients were responding to management treatments.

During the second month CP values differed for *Imperata cylindrica* (1-way ANOVA F=9.25; df=2, 24; p=.001), *Saccharum spontaneum* (1-way ANOVA F=14.17, df=2, 14; p=.000) and *Vetiveria zizanioides* (1-way ANOVA F=15.89; df=2, 19; p=.0001) between management treatments. CP values were consistently higher for grasses from cut-burnt areas and lower from cut areas (Tukey,s multiple range test p<.05) (Table 8).

In case of ADF content the difference was significant in *Saccharum spontaneum* (1 way ANOVA F=9.76, df=2, 14; p=.002) and it was higher from the cut treatment.

3.1.7. Ungulate use

There was consistently lower use of unmanaged areas by ungulates in all 3 *phantas* for first month and second month; while no particular pattern in use of cut, burn and cut-burn areas were detected statistically. In third month more significant use of unmanaged areas seen in two *phantas*.

3.2. Grazing lawns

3.2.1. Species composition

Dry above ground biomass indicated that dominant grass species in grazing lawns and neighbouring grasslands were *Imperata cylindrica, Vetiveria zizanioides, Saccharum spontaneum,* and *Desmostachya bipinnata.* The percentage contribution by these species, however, differed between grazing lawns and grasslands (Table 9). The coarser grass species like *Vetiveria zizanioides, Saccharum spontaneum,* and *Desmostachya bipinnata* were found to occur at low densities in grazing lawns. Grazing lawns had greater diversity of species and dicots contributed over 21.3% biomass compared to only 3.3% in grasslands. Majority of the dicot species were highly palatable (Appendix 2).

Table 8. Mean CP (crude protein), ADF (acid detergent fibre), L(lignin) and AIA (acid insoluble ash) values pooled from Baghaura, Lamkauli & Khauraha *phantas* from fenced area following second month of treatment in Royal Bardia National Park, Nepal.

Imperata	%CP	%ADF	%L	%AIA
Burn	9.65	38.92	8.56	4.75
	(0.48)	(0.33)	(1.15)	(0.23)
CB	11.17	38.80	8.21	4.46
	(0.43)	(1.17)	(1.12)	(0.14)
Cut	8.31	41.46	13.50	4.52
	(0.42)	(0.95)	(2.03)	(0.42)
Unm	3.74	46.34	14.06	5.54
	(0.11)	(1.11)	(1.92)	(0.23)
Saccharum				
Burn	9.91	42.67	8.56	3.06
	(0.44)	(0.32)	(2.30)	(0.07)
C-B	10.86	39.95	8.78	3.84
	(0.26)	(0.69)	(0.92)	(0.24)
Cut	8.38	43.22	13.56	3.68
	(0.24)	(0.39)	(5.25)	(0.81)
Unm	5.02	45.98	11.03	4.46
	(0.41)	(0.49)	(1.99)	(0.18)
Vetiveria				
Burn	11.02	39.19	9.49	4.39
	(0.49)	(1.58)	(1.62)	(0.18)
C-B	10.94	39.97	12.21	3.83
	(0.41)	(2.12)	(2.08)	(0.23)
Cut	7.60	41.49	10.93	3.64
	(0.48)	(1.34)	(1.78)	(0.33)
Unm	3.54	45.94	13.58	4.76
	(0.28)	(0.46)	(1.11)	(0.25)

C-B= Cut-Burnt treatment; Unm= Unmanaged treatment.
Values in parenthesis are standard errors.

Table 9. Percent dry above ground biomass composition of species on grazing lawn(Sg) and neighbouring grasslands (Tg) in Royal Bardia National Park, Nepal.

Species	Sg Mean(SE)	Tg Mean(SE)
Imperata cylindrica	54.9(9.5)	61.3(11.5)
Vetiveria zizanioides	11.5(4.7)	19.5(6)
Saccharum spontaneum	1.38 (1.61)	6.3(2.5)
Desmostachya bipinnata	1.77(1.61)	6.67(6.09)
Dicot spp.	21.3(3.9)	3.3(0.7)
Others	9.15(6.5)	2.39(1.21)

To test the hypothesis that grazing lawns differ in herbal community structure from neighbouring tall grasslands a discriminant function was developed based on plant species biomass, plant species numbers, and average plant species height in the herb strata. For the discriminant analysis *dicotilidonous* plants were pooled except *Oxalis* spp., since *Oxalis* was likely to contribute substantially to herbivore grazing on grazing lawns. Out of a total of 32 variables, the discriminant function selected 6 of them (Appendix 3). *Dicots, Fimbristylis, Oxalis*, and *Saccharum narenga* contributed ($p<.1$) to the discriminant function. The discriminant function had an overall efficiency of 90% correct classification of the 108 quadrats. Correct classification of grazing lawn quadrats was 86%, while 97% of grassland quadrats were classified correctly. This analysis suggests that the grazing lawns differed substantially in community structure from grasslands.

Dry biomass from grazing lawn was lower in comparison to tall grasslands (paired t-test $p=0.096$). However, after 50 days of grazing free growth within fenced area, above ground biomass of grazing lawns was similar to that of grasslands (paired t-test $p>0.2$).

3.2.2. Forage quality

In general growing tips of plants from grazing lawns had higher crude protein values (paired t-test $p<.001$), lower ADF (paired t test $p<0.001$) and lignin (paired t-test $p<.01$) than neighbouring grasslands. Of the three dominant species compared, crude protein values were greater in *Imperata cylindrica, Saccharum spontaneum* and composite sample growing on grazing lawns, *Vetiveria zizanioides* did not show a difference between grazing lawns and grasslands for CP values (Table 10, Figure 11). *Imperata cylindrica* samples from grazing lawns were lower in ADF, AIA, and lignin and total indigestible component (AIA + lignin) in comparison to samples from grasslands (paired t-test $p<0.1$). *Vetiveria zizanioides* and *Saccharum spontaneum* samples from grazing lawns and grasslands did not differ (Paired t-test $p<0.1$) for lignin, AIA, and indigestible component (AIA + lignin). However, ADF value of *Vetiveria zizanioides* from grazing lawn was lower than that from grasslands (Table 10; figure 11). The composite samples from grazing lawns had higher CP values, lower ADF, lignin and total indigestible component (lignin + AIA) values in comparison to grassland composite samples (Figure 11).

Grazing lawns had higher mineral contents in their growing shoots in comparison to growing shoots of neighbouring grasslands. Specific minerals that were in higher concentrations were Na, K, Cu, Fe, & Zn (paired t-test $p<0.1$). Comparison of mineral content of the 3 dominant species and a composite sample from grazing lawn and neighbouring grasslands gave similar results (Table 11; Figure 8, 9, 10).

Comparison of minerals in the soil between grazing lawn and associated tall grassland showed significant difference (paired t test $p<.1$) for P_2O_5, Mno, Fe_2o_3, Cao, Mgo and Cu except for sodium and potash (Table 12).

Table 10. Comparison of nutritive value between grazing lawn and tall grassland in Royal Bardia National Park, Nepal.

Species		% CP		% ADF		% AIA		% LIGNIN		% AIA+L	
		Sg	Tg	Sg	Tg	Sg	Tg	Sg	Tg	Sg	Tg
Co	M	#9.67	#8.1	*38.3	*42.7	5.0	4.97	#5.8	#6.5	#10.8	#11.5
	S	0.70	0.54	1.09	1.15	0.2	0.42	0.72	0.51	0.81	0.71
Im	M	*8.23	*6.9	*40.39	*41.3	4.9	5.32	#5.3	#7	#10.2	#12.3
	S	0.4	0.57	0.47	1.28	0.3	0.5	0.46	0.77	0.5	0.95
Sa	M	*9.17	*7.3	42.51	44.10	5.1	3.97	4.71	6.57	9.75	10.54
	S	0.36	0.51	1.12	0.26	0.8	0.47	0.11	1.17	0.81	1.28
Ve	M	11.05	10.3	*37.2	*41.0	*5.6	*4.2	5.84	6.77	11.5	11.00
	S	0.49	0.2	0.25	0.54	0.5	0.21	0.8	0.55	0.45	0.5

Means differed at #= p<.1, *= p<.05 , paired t-test.

CP= Crude protein; M=Mean; S=Standard error
ADF= Acid detergent fibre; AIA= Acid insoluble ash
Co=Composite sample; Im=*Imperata cylindrica*;
Ve=*Vetiveria zizanioides*; Sa= *Saccharum spontaneum*
Sg= Short grass; Tg= Tall grass

Table 11. Comparison of minerals between grazing lawn and tall grassland for composite and dominant grass samples in Royal Bardia National Park, Nepal.

Mineral		*Composite*		*Imperata*		*Saccharum*		*Vetiveria*	
		SG	TG	SG	TG	SG	TG	SG	TG
P	M	1720	2059	632	814	1635	1484	2266	2241
	S	103	232	452	444	67.6	59.7	124	197
Zn	M	29.3	31.2	143	204	*22	*27	*30	*24
	S	2.29	2.35	166	201	1.51	1.25	2.77	2.13
Fe	M	795	528	*357	*598	397	422	*539	*399
	S	186	18.5	245	403	49.9	34.8	91.1	84.6
Mn	M	52	55.5	245	386	37.4	34.4	*63	47
	S	4.34	4.36	241	348	2.86	2.56	12.2	5.58
Ca	M	4992	4307	*2002	*2774	4743	4239	3797	3519
	S	481	263	1569	1653	397	434	125	253
Cu	M	35.8	34.7	642	639	9.8	8.2	40.3	31.2
	S	7.39	8.98	737	766	2.02	2.2	14.5	5.33
Mg	M	1805	1563	1523	1392	1345	1378	1780	1899
	S	169	99.7	99.6	176	66.3	82.6	94.9	93.9
Na	M	*289	*230	*348	*913	*1059	*289	254	263
	S	24.3	29.2	24	1005	1129	24.3	19.5	33.3
Kx100	M	$118	$103	103	94	*118	*103	132	133
	S	7.5	5.4	4.9	7.0	7.5	5.4	3.5	6.7

Means different at *= <.1, $ = <.05, paired t-test

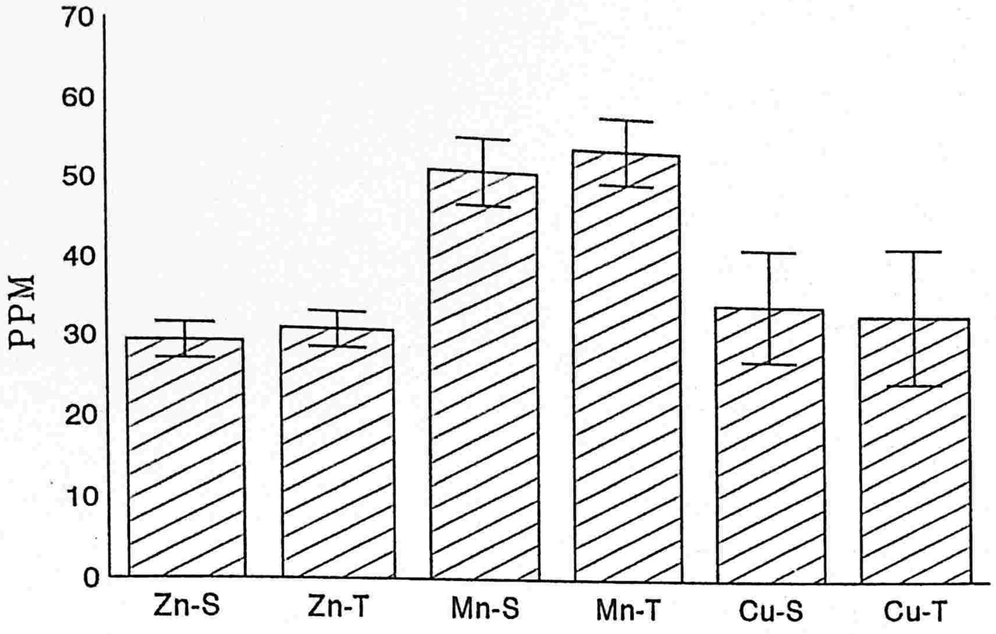
All values are in ppm ; M=mean; S=Standard error.

Table 12. Comparison of soil minerals between grazing lawn and tall grassland in Royal Bardia National Park, Nepal.

Elements % age	Parameter	Short grass	Tall grass
$P_2 0_5$	Mean#	0.1985	13.80
	SE	0.0087	0.017
Mno	Mean#	0.0824	3.0288
	SE	0.005	0.2575
$Fe_2 o_3$	Mean#	5.635	3.3458
	SE	0.2575	0.4953
Cao	Mean*	1.1995	1.6862
	SE	0.0922	0.1357
Mgo	Mean+	2.1233	1.8716
	SE	0.1504	0.2891
Cu (ppm)	Mean#	26.9166	14.0391
	SE	1.7013	6.2289
$Na_2 o_3$	Mean	1.0275	0.9983
	SE	0.0543	0.1177
$K_2 o$	Mean	3.0008	1.99
	SE	0.0733	0.2726
Soluble N	Mean	1.9567	1.5138
	SE	0.2582	0.109
pH	Mean	8.2	8.4667
	SE	0.0745	0.1743
Moisture	Mean	13.925	16.3576
	SE	1.7038	2.9666

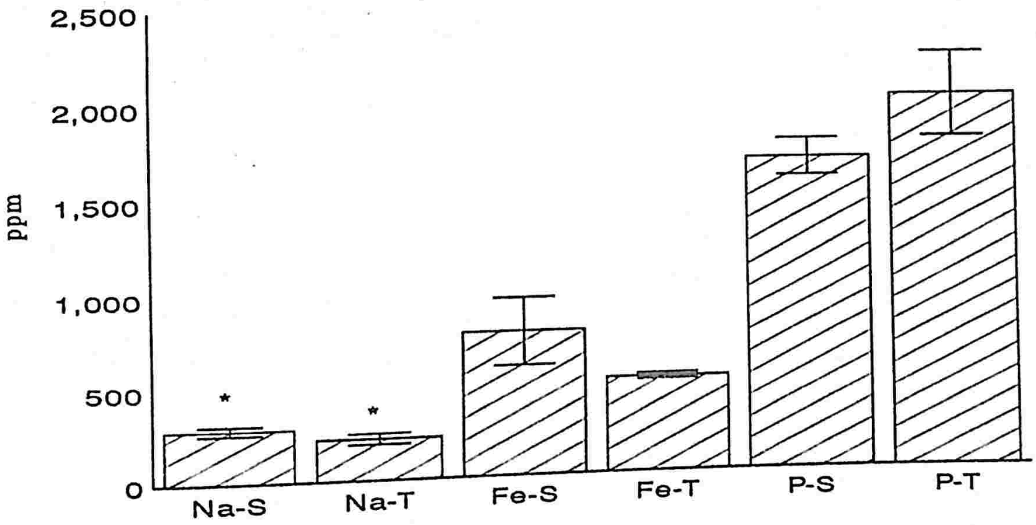
Means differed at #=p<.1, +=p<.05, *=p<.01, paired t-test; SE= Standard error.

Figure 8. Trace mineral content of forages from grazing lawns and grasslands.



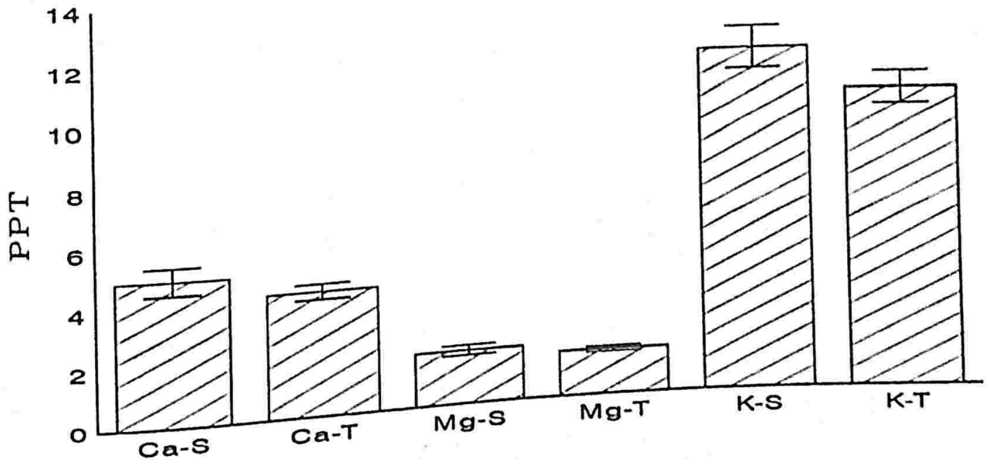
S= grazing lawn, T= grassland

Figure 9. Na, Fe and P content of composite forage from grazing lawns and grasslands.



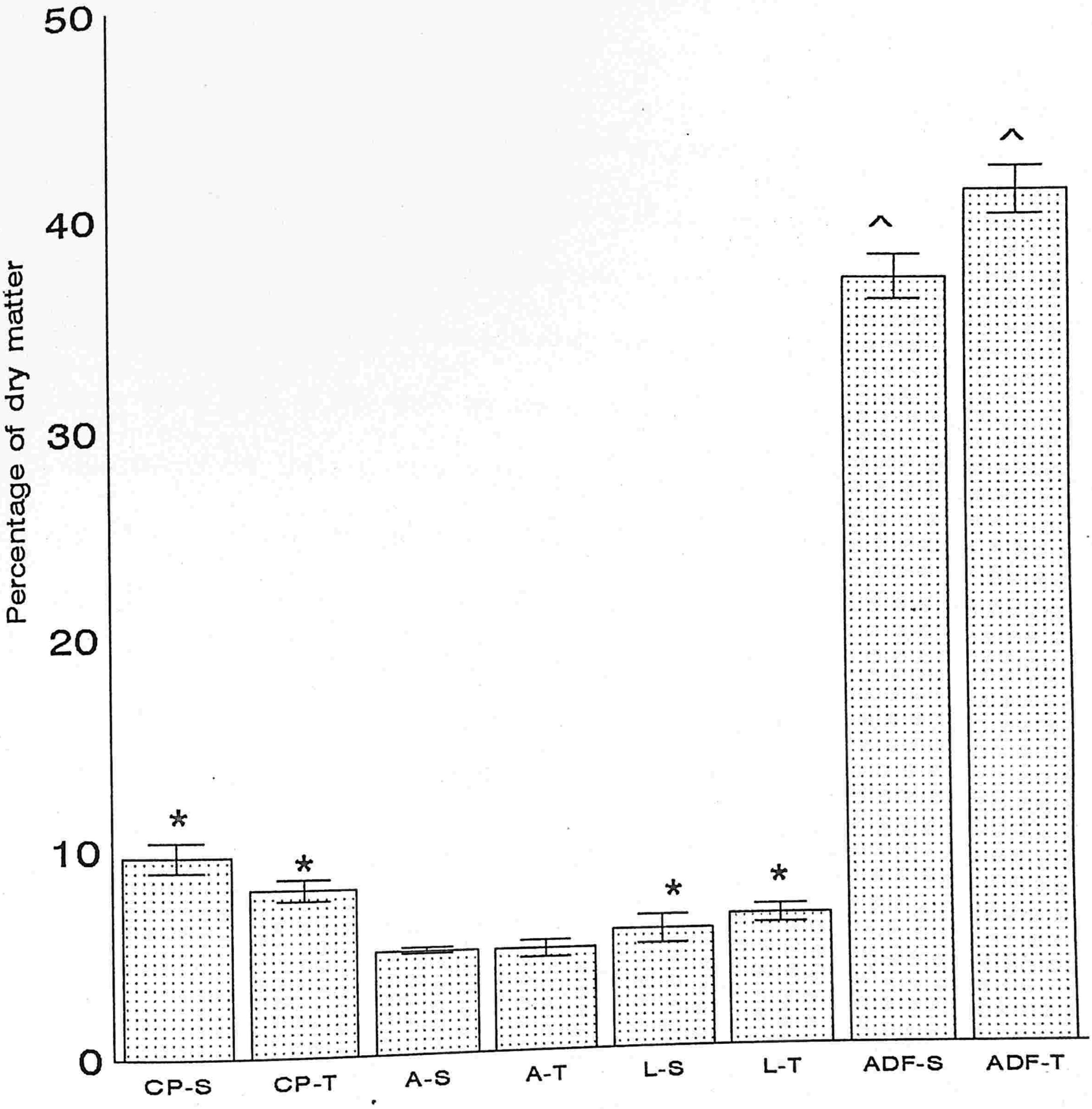
S= grazing lawn, T= grassland, * different at $p<0.1$, paired ttest.

Figure 10. Ca, Mg and K content of composite forage from grazing lawns and grasslands.



S= grazing lawn, T= grassland

Figure 11. Nutritive value of composite forage from grazing lawn (S) and grassland (T).



CP- crude protein, L- lignin, ADF-acid detergent fiber,A=acid insoluble ash
Pairs different at * p<0.1, ^ p<0.05, paired ttest.

4. DISCUSSION AND MANAGEMENT IMPLICATION

4.1. Is continuous harvest and burning depleting grassland resources ?

Several experimental plots would need to be monitored for several years to study the deterioration of the grassland quality and to gain an insight into this pertinent management question. With a short term study like this, it was only possible to probe the above topic. Soils of the *terai* are low in phosphates and nitrogen (Dabadghao and Shankaranarayan 1973). Continuous removal of grass biomass from the ecosystem for human use and annual burning were likely to deplete phosphates and highly volatile nitrogen from the system (Daubenmire 1968). If indeed the system were depleted of these elements, then their addition in the form of a pulse dose of fertiliser should result in an increase in phyto-biomass and grassland nutritive quality. My results in all the three *phantas* unanimously show that there was no drastic response of above ground biomass to either DAP or urea treatment. Though by the end of third month (most grass species were flowering by then) the plots treated with urea tended to have higher green biomass (not statistically different) in comparison to DAP and untreated plots (Figure 4, 7). DAP and urea treatment did not alter the nutritive quality (crude protein and lignin content) of the forages.

My results do not reject the null hypothesis of no difference in above ground production and forage quality between different fertiliser treatments. My results suggest that Bardia grasslands are not adversely effected by the current rates of biomass removal. The system was highly productive with high rainfall (Figure 2). It appears that the grassland ecosystem can sustain the current levels of nitrogen loss since nitrogen is likely to be replenished from atmospheric nitrogen through heavy rainfall, by deposition of silt through periodic flooding and fixation in the soil by microbes and legumes.

4.2. Which management treatment is ideal for ungulate use ?

Several factors governs the foraging choices of ungulates (Krueger et al. 1974). Primary amongst them are the nutritive quality (CP, digestibility, mineral content etc.) and availability (Lippke 1980; Sinclair 1975; Van Soest 1987). The management strategy of cutting, burning and cutting-burning were likely to have different responses in terms of both nutritive quality and availability. I analysed and tested data for both, nutritive quality as indexed by a) crude protein b) lignin c) acid detergent fibre and d) acid insoluble ash content and availability as above ground green biomass. There were significant differences between management treatments for both forage quality and quantity for all three months in all three *phantas*. The forage samples from cut-burnt plots consistently had greater crude protein values for all three months as also reported by Moe and Wegge (1997). During the first month crude protein values of forages from cut-burnt plots were almost double in comparison to forages from cut plots. Cut plots consistently had lowest crude protein values for all the three months, however, the difference in magnitude reduced as forages matured. Acid detergent fibre content of forages from cut plots was higher in comparison to that of forages from cut-burnt and burnt plots. There were no statistically detectable differences amongst lignin and acid insoluble ash content of forages from the different management treatments. There was however, a trend for forages from cut-burnt and burnt plots to have lower indigestible (lignin + AIA) material in comparison to forages from cut plots.

The above ground biomass showed a contrary response in comparison to forage quality to management treatments. Cut plots had greater green above ground biomass following the first two months of treatment. Grasses were harvested at 5-8 cm above the ground, while cut-burnt and burnt areas were almost devoid of above ground plant structures for about a week. Burning was also likely to raise soil temperatures 1-2 cm below the surface (Shankar 1978). Both of these factors would retard plant growth. Cut areas were quick to respond with a fresh flush of shoots and also with elongation of shoots that were cut. The lag phase for this response for burnt and cut-burnt areas was more. Therefore, by the end of the first month cut, areas had greater green above ground biomass. This difference persisted in some areas even in the second month. By the end of the third month the above ground biomass between the three treatments did not differ statistically (Figure 4,5,6,7). Above ground biomass was only an index of availability to ungulates. The relationship between ungulate use of AGB is likely to be curvilinear or even parabolic (Noy-Meir 1975). Initially after a burn, the flush of new growth would have low use due to its small height and low volume. As the grass mat grows beyond a certain height (critical cropping height) ungulate use increases almost linearly with increase in AGB (Noy-Meir 1975; Sinclair 1975). Above a certain height forage volume decreases even though AGB increases (McNaughton 1984). At the same time nutritional factors also start to play a role in forage selection by ungulates. As forages mature they tend to become more lignified, less digestible, and their protein content decreases (Sinclair 1975). At this stage ungulate use plateau off or even decreases.

The Bardia grassland use by ungulates conforms to the above pattern. Initially, during the first month grazing significantly reduced the above ground biomass of cut plots. During this time the cut-burnt and burnt plots had grass growth likely below the critical cropping height. It would be unprofitable for ungulates to graze areas that are cut-burnt or burnt in comparison to cut plots at this growth stage. However, by the second month, the cut-burnt and burnt areas had achieved high forage volume which was of better quality (higher in CP and lower in lignin) then cut areas. During this time ungulates grazed burnt and cut-burnt areas more intensively. By the third month no particular pattern for any of the three treatment was evident from the three grasslands. There was a trend of increased ungulate use of unmanaged grasslands (though not statistically significant). By the third month grasses were mature and flowering in the treatment plots. While in the untreated control plots tall grasses had been flattened by rain and new shoots were sprouting from amidst the fallen mature vegetation. My results contradict those of Moe and Wegge (1997) who found greater use of cut-burnt areas by ungulates throughout their study period.

The above results have an applied management significance. In the past, the 3 grasslands used to be burnt annually as a management practice after the villagers had harvested the grasses. Recently controlled burning has been limited to cover about 50% of the grasslands. This practice is an improvement over previous one, since cut areas provide a green flush much faster than cut-burnt areas. Such cut unburnt areas may even be critical immediately following a fire, which would reduce foraging areas till regrowth appears and reaches the critical cropping height. It appears that unmanaged grasslands also play an important role in nutrition of Bardia ungulates. Also, such unmanaged areas with tall grasses may be critical habitats for fawning, cover for hunting (Sunquist 1981), and refuges for endangered species like the Bengal florican (*Eupodotis bengalensis*). The ideal management strategy for grasslands of Bardia should be to maintain a mosaic of areas that are cut, cut-burnt and areas of unmanaged tall grasses. Cutting should be done in two phases spaced 20 days to 1 month apart; Similarly some cut areas should be burnt at different times spaced 0.5 to 3 months apart. Cut, cut-burnt and unmanaged areas should be rotated on a time scale from 1 year to 3 years. Such a management strategy would insure that there is always availability of nutrient rich palatable forage for the ungulates of Bardia while simultaneously the other values of grassland system of *terai* (e.g. cover) were not compromised. Since most grassland systems of are successional stages, progressing gradually towards woodlands, such a management scheme would also tend to retard this succession.

4.3. Grazing lawns

4.3.1. Soils

Compared to "hotspots" and "grazing lawns" described by McNaughton (1984) in the Serengeti ecosystem (large areas measured in square kilometres), the short grass patches observed in the Bardia grasslands were much smaller (<0.5 ha.). Therefore, the scale of comparison between grazing lawns and neighbouring grasslands was at micro-level compared to hotspots of the Serengeti. Due to this micro-scale one would expect the underlying edaphic characteristics of the soil of grazing lawns to be similar to that of grasslands. The particle size of soils from both areas were similar and the soil could be classified as alluvial-silt. Other physical parameters like soil moisture and pH (alkaline) also did not differ between grazing lawns and grasslands. However, soils from grazing lawns were having higher concentrations of iron, copper, magnesium, sodium, and potassium while concentration of phosphorus, calcium and manganese were low in comparison to neighbouring grassland soils. Soils of grazing lawns tended to have higher nitrogen content and lower pH in comparison to grassland soils but these differences were not statistically significant.

There are two possible explanations for the above differences in the soil mineral composition. (i) abiotic phenomenon like (a) different origins for the underlying soils of gazing lawns and surrounding grasslands and/or (b) differential deposition of soils in these areas due to floods. (ii) biotic factors like (a) growth of different plant communities with different minerals absorption rates and/or (b) deposition of certain minerals through dung due to different intensity of use of the two areas (Day and Delting 1990). In light of the data of the present study, the biotic factors seem to be a more likely explanation. It seems unlikely that within a single grassland such interspersed small patches would have different parental origins for the soils. It is also unlikely that there would be differential deposition during flooding since there were no elevational gradients or depressions associated with grazing lawns and neighbouring grasslands.

4.3.2. Community structure and species composition

Predation pressure reduces the competition and promotes species richness and diversity within a community (Edroma 1981, Huffaker 1971). Grazing lawns had greater species richness and diversity in comparison to neighbouring grasslands. Over 21 % of the biomass of grazing lawns was from dicot forbs of which over 80 % were palatable (9 species) and remaining (9 species) were likely inedible. In comparison dicots contributed only 3 % to the total biomass of grasslands. More grasses growing on grazing lawn showed prostrate grazing adapted forms, forming a dense mat near the soil surface. The discriminant analysis function that correctly classified 90 % of the quadrats to grazing lawns and grasslands, took into account species composition, biomass, number and species height attributes of plant community structure. Therefore, the grazing lawns had distinctly different plant community compared to grasslands; in accordance to prediction of A of my initial hypothesis.

The relation of above ground biomass from grazing lawns, grasslands and grazing excluded areas of grazing lawns (exclosures) were as follows:

Grassland > exclosure > grazing lawn

(Underlined areas had similar above ground biomass, Tukey's multiple range test $p<0.05$).

The increase in plant biomass by protection from grazing suggests that grazing lawns were maintained by continuous grazing pressure. Exclusion of grazing was likely to convert grazing lawns into grassland communities. It seems likely that natural disturbances like fire, floods, or even high intensity grazing by mega-herbivores (elephants and rhinos) would open up tall grasslands. These areas would then be maintained as grazing lawns by grazing ungulates in a dynamic equilibrium.

4.3.3. Forage quality

Grazing lawns were maintained at the critical cropping height by continuous grazing pressure. This facilitated lateral tillering of grasses with continuous green growth (McNaughton 1984). Comparing forage samples sampled by quadrats in grazing lawns and grasslands for nutrient quality were bound to show significant differences between lush green growth of grazing lawns and coarse tall grasses of grasslands (Falvey et al. 1981; McNaughton 1988). Ungulates are selective foragers. Depending on the mouth size the level of selection differs (Jarman 1974). Bardia grasslands were grazed primarily by chital (*Axis axis*) and swamp deer (*Cervus duvauceli duvauceli*), both capable of high selectivity due to their medium size mouths. Sambar (*Cervus unicolor*), hog deer (*Axis porcinus*), rhino (*Rhinoceros unicornis*), elephant (*Elephus maximus*), and barking deer (*Muntiacus muntjac*) were some of the other herbivores that used these grasslands occasionally. Due to the selective ability of the primary grazers, only the nutrient rich highly digestible plant parts would be consumed. I, therefore, sampled only the growing tips and fresh leaves of grasses and forbs growing in the grassland and grazing lawns for nutritive analysis.

New flush of vegetation growing on the grazing lawn had higher nutritive quality in comparison to new flush of grassland vegetation. All samples of grazing lawns had greater crude protein values and lower lignin content than grassland samples. Vegetation of grazing lawns was higher in sodium, potassium, iron and calcium (though the values were statistically not significant for calcium) content. Mineral content of forage samples from grazing lawns as well as grasslands were well above the minimum requirements of ruminants except for sodium and magnesium and were marginal for phosphorus, calcium and zinc. Sodium especially was found in extremely low concentrations (Church 1984; Robbins 1983; Van Soest 1982). Thus, grazing lawns not only provided more digestible forage with higher crude protein but also provided higher concentration of deficient minerals like sodium. *Oxalis* spp. growing abundantly on grazing lawns had high concentration of sodium (over 400 ppm), magnesium (over 3550 ppm) and phosphorus (over 2200 ppm), minerals deficient in the ecosystem.

The above ground biomass albeit was greater for grasslands in comparison to grazing lawns. However, very little proportion of this biomass would be actually palatable food for selectively feeding ungulates (Sinclair 1974). Besides, almost all the above ground growth beyond the critical cropping height in grazing lawns would be highly palatable to ungulates. The foraging efficiency i.e., biomass intake and nutrient intake per bite as well as number of bites per unit time were likely to be higher for grazing lawns. Grazing lawns thus provided highly nutritious forage in high density per unit volume in comparison to grasslands. Ungulates would therefore, graze more intensively in grazing lawns and in turn provide manure via urine and dung promoting plant growth (Day and Delting 1990), and plant diversity by keeping the community canopy height close to critical cropping height. Thus, grazing lawns would be maintained by continuous cycle of gazing enriched by animal manure and different plant community structure.

My study is in an agreement with Moe and Wegge's (1997) results in recommending cutting and burning as the best strategy to enhance the amount of nutritive rich forage. However, it goes a step further to show the importance of other management (and un-managed) options and wildlife values. The study of grazing lawns should be considered as preliminary, since the number of grazing lawns studied was small (six). The trends that emerge even with a limited sample size are ecologically interesting and merits a more detailed investigation. A long term study with exclosures on 15-30 grazing lawns from different *phantas* would provide conclusive answers on succession, mechanism of nutrient, and mineral enrichment and equilibria of grazing lawn communities. It seems that the grazing lawns are natures way of managing nutrient rich grazing conditions amongst coarse tall grasslands.

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6. APPENDICES

Appendix-1. Mammalian fauna of Royal Bardia National Park, Nepal

Artiodactyla

Suidae

1. Wild boar, *Sus scrofa*

Cervidae

2. Barking deer, *Muntiacus muntjac*
3. Chital, *Axis axis*
4. Hog-deer, *A.porcinus*
5. Swamp-deer, *Cervus duvauceli duvauceli*
6. Sambar, *Cervus unicolor*

Bovidae

7. Nilgai, *Boselaphus tragocamelus*
8. Black buck, *Antilope cervicapra*
9. Four-horned antelope, *Tetracerus quadricornis*
10. Goral, *Nemorhaedus goral*

Rhinoceritidae

11. One horned rhinoceros, *Rhinoceros unicornis*

Elephantidae

12. Asian elephant, *Elephus maximus*

Felidae

13. Tiger, *Panthera tigris*
14. Leopard, *P.pardus*

15. Jungle cat, *Felis chaus*

16. Leopard cat,Felis bengalensis

Viveridae

17. Large Indian civet, *Viverra zibetha*

18. Small Indian civet, *Viverricula indica*

Herpestidae

19. Common mongoose, *Herpestes edwardsi*

Hyaenidae

20. Striped hyaena, *Hyaena hyaena*

Canidae

21. Indian fox, *Vulpes bengalensis*

22. Jackal, *Canis aureus*

23. Indian wild dog, *Cuon alpinus*

Ursidae

24. Sloth bear, *Melursus ursinus*

Cetacian

25. Dolphin, *Platanista gangetica*

Mustelidae

26. Smooth coated Indian otter, *Lutra perspicillata*

27. Common otter, *Lutra lutra*

28. Ratel, *Mellivora capensis*

Leporidae

29. Indian hare, *Lepus nigricollis*

Chiropteridae

30. Short-nosed fruit bat, *Cynopterus sphinx*

31. Common yellow bat, *Scotophilus heathi*

32. Indian pipistrelle, *Pipistrellus coromandra*

33. Fulvus fruit bat, *Rousettus leschenaultii*

Sciuirdae

34. Large flying squirrel, *Petaurista petaurista*

35. Five-striped palm squirrel, *Funambulus pennanti*

Hystricida

36. Indian porcupine, *Hystrix indica*

Muridae

37. House rat, *Rattus rattus*

Primates

38. Common langur, *Presbytes entellus*

39. Rhesus [redacted] monkey, *Macaca mulatta*

Appendix 2. List of grass species found in the study *phantas* and grazing lawns in Royal Bardia National Park, Nepal.

Bothriochloa intermedia

Cyanodon dactylon

Desmostachya bipinnata

Imperata cylindrica

Eragrostis tremula

Eragrostis poaides

Fimbristylis spp.

Saccharum spontaneum

Vetiveria zizanioides

Dicots

Edible

Euphorbia prostata

Evolvulus alsinoides

Indigofera linifolia

Justicia simplex

Nelsomia canescens

Oldenlandia coccinea

Oxalis corniculata

Trigonella emodi

Inedible

Androsace primullifolia

Argimone mexicana

Blumea mollis

Canscorea diffusa

Exacum spp.

Oscimum spp.

Salvia plebeija

Youngia japanica

Unidentified (local name, Rato dath bhayeko khareto jasto)

Appendix 3. Discriminant analysis for classification of quadrats from grazing lawns and grasslands.

Summary Tables

Step	Action entered Removed	Vars in	Wilk's Lambda	p< sig.	Func 1
1	DHT	1	0.8064	0.0001	0.6359
2	DICOTNO	2	0.6948	0.0001	0.6757
3	SNHT1	3	0.6185	0.0001	0.5233
4	FNO	4	0.5723	0.0001	0.4569
5	OCTNO	5	0.4986	0.0001	0.3407
6	OCTHT	6	0.4986	0.0001	0.3328

Canonical discriminant functions

Fcn	Eigen value	% of Vari	Cum pct	Cano corr	Wilk's Lambda	Chi-square	df	Sig p<
1*	1.01	100.0	100.0	0.71	0.4986	71.684	6	0.0001

Classification results

Actual groups	No. of cases	Predicted	Group membership
Group 2	72	62	10
		86.1%	13.9%
Group 3	36	1	35
		2.8%	97.2%

Percent of grouped cases correctly classified: 89.81%