THE CHARACTERISATION OF FEED RESOURCES IN CROP-LIVESTOCK SYSTEMS AND ITS IMPLICATIONS FOR THE DEVELOPMENT OF IMPROVED FEEDING STRATEGIES - A CASE STUDY FROM NEPAL.

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ABSTRACT

Data describing the use of feed resources by buffalo, cattle and goats were collected during a 15 month monitoring study on 28 crop-livestock farms in the Eastern Hills of Nepal. These were analysed to determine the effects of study site, farmers' ethnic group and season on a number of parameters describing the categories of feed observed and their mode of utilisation. Farmers belonging to *Rai / Limbu* ethnic groups generally appeared to keep fewer animals overall (and fewer buffalo in particular) and have more restricted access to feed resources than those belonging to *Chetri / Brahmin* ethnic groups. There was also evidence that the former may have found the maintenance of feed supplies during the dry season more taxing. Distinct seasonal patterns in feed utilisation were observed with monsoon season diets based on grasses giving way to crop residue-based diets during the dry season. However, clear site effects were observed in the composition of diets during the different seasons. For example, the relative extent of tree fodder utilisation during the dry season differed by more than 100% across the four study sites. This, and other, observations illustrate the need for local planning of optimum feeding systems. The need for the type of background information generated by the study for developing and promoting the uptake of improved feeding strategies in smallholder systems is also emphasised and the methodological implications of this are discussed.

INTRODUCTION

Feed shortages have been identified widely as a major constraint to improved productivity of livestock kept under smallholder conditions in developing countries. It has also been recognised that the nature and severity of these shortages may be affected by a range of factors that operate in different farming systems (e.g. ILCA, 1987). Despite this widespread perception, there have been few attempts to identify the principal sources of variation in the supply and utilisation of feed resources *at the farm level* and then to quantify their effects. Without information at this level of detail, effective planning of research and targeting of extension recommendations for assisting smallholder farmers to optimise supplies of nutrients to their animals must be compromised. The study described here was designed to redress this deficiency for a "representative", smallholder, mixed farming system.

The integrated, crop-livestock system of the Middle Hills (1100 - 1700 metres above sea-level; m.a.s.l., annual rainfall c. 1800mm concentrated between June and September, 20-30°C in summer and 8-18°C in winter) of Nepal was selected for this case study for the following reasons:

- the pre-eminence in Nepal of feed shortages amongst other resource constraints has been confirmed by macro-level studies (Schreier *et al*, 1991). Of 71 administrative districts in the country, 50 were found to be less than 80 *per cent* sufficient in supplies of livestock feed. Whilst the country was found to produce a 25 *per cent* surplus in food for its human population, a 40 *per cent* deficit in feed was observed.;
- the terraced land of the Middle Hills must support very high human population densities. These have required the intensification of production from a system in which livestock are tightly integrated (Wyatt-Smith, 1982; Hopkins, 1983). Surplus biomass from cropping enterprises forms a significant proportion of available feeds. However, farmers also perceive that agricultural production would not be feasible without livestock to provide manure and draught power (Thorne, 1993). This important role is reflected in the high livestock population densities that are typically observed, in spite of the practical difficulties associated with keeping livestock on hillsides. The survey results of Gurung *et al* (1989) indicate a mean holding of 6.6 large ruminants on farms in the eastern Middle Hills;
- the farming systems of the Middle Hills have probably operated for centuries and are highly developed to deal with the difficulties of farming intensively in a fragile ecosystem. As a result, farmers also possess detailed systems of technical knowledge (Chand *et al*, 1990) that support their decision making. These encompass information on the factors that affect feed quality and approaches to planning optimum feeding strategies - as described by Rusten and Gold (1991) and Thapa *et al*, (in press) for tree fodder. The detailed study of feed resource utilisation within this system provides, therefore, a useful overview of the extent to which relatively sophisticated, smallholder farmers are equipped to manage feeding strategies and where research results might supplement their existing capabilities;
- the study system is generally thought of as being in a state of flux as land holdings fragment with increasing human population pressure and environmental degradation reduces farmable land areas. Farmers have developed a number of strategies for coping with the effects of these changes.

For example, Carter and Gilmour (1989) have described significant increases in the planting of trees on crop land for the production of fodder and fuelwood as areas of common property forest land have been reduced. However, in relation to feed resources, Schreier *et al* (1991) have predicted that, by the year 2000, sufficiency will have been reduced from 43 *per cent* to 26 *per cent.* It is envisaged that the information generated by this study will assist in developing strategies to counter the effects of these changes.

This paper summarises the nature of the feed resources available in the study system and the extent to which this may be influenced by several key factors. A number of methodological considerations are also discussed.

MATERIALS AND METHODS

The 15-month, on-farm study described in this series of papers was established in June, 1993 in the *Terathum* and *Dhankhuta* Districts of Eastern Nepal. Data describing feed utilisation and animal performance on the smallholder farms of the Middle Hills were collected.

Stratification and Selection of Participating Farmers

A series of field visits allowed semi-structured interviews with farmers and a static, farm characterisation survey to be conducted in preparation for the main study. These indicated that three factors - site, ethnicity of the farm household and season - were likely to be of key importance in influencing feed supplies to livestock on farms in the study area (Thorne, 1993). The study was stratified and participating farmers were selected in order to allow this hypothesis to be tested by evaluating the main effects of these three factors and their interactions.

Site Stratum

The site *stratum* was, essentially, a composite factor encapsulating variation due to a combination of environmental and socio-economic factors. Interviews with farmers (Thorne, 1993) suggested that these factors might include water availability (from direct precipitation and from irrigation); soil stability and fertility; access to markets and past exposure to new technologies. The four villages, contrasting in these respects, that were selected to represent the site *stratum* in the study were *Angdim* (relatively humid with the best market access for milk and vegetables and widespread involvement in local research and extension programmes.), *Ankhisalla* (dry area with limited access to markets for livestock and other products), *Jirikhimti* (humid but with limited access to markets; research-outreach activities in parts) and *Phakchamara* (dry but with marketing arrangements for milk established; on-farm site for livestock research.).

Ethnicity Stratum

A number of cultural factors may affect the behaviour of the farm household and enhance or compromise its capacity to farm effectively. These may also significantly affect the feeding and management of livestock (Abington, 1992). The basic importance of ethnicity in determining this behaviour was confirmed by the semi-structured, individual interviews that were conducted with farmers belonging to both of the main ethnic groups (*Rai / Limbu* and *Chetri / Brahmin*) living at the study sites. The two groups generally percieved their relative prosperity and differences in practices and opportunities consistently. *Rai / Limbu* families were believed to devote more time to religious observation and sacrifice more animals in the course of this, to use more alcohol, to be more dependent on cropping and to use land in a less than optimum manner whilst *Chetri / Brahmin* farmers were considered more innovative, better educated, to keep more animals and to have better land. Several of these differences appeared likely to impinge on the utilisation of feed resources. Therefore, ethnicity was included as the second, major *stratum* within the study.

Season Stratum

Information gathered during the preparatory work undertaken with farmers (Thorne, 1993) was consistent with earlier reports (Conlin and Falk, 1979; Gatenby *et al*, 1989) of distinct seasonal differences in feed utilisation on farms in the Middle Hills. On completion of the study, the existence of these marked seasonal patterns could be confirmed by visual examination of the feed compositions recorded on individual farms (e.g. Figure 1a).

The key feature of this seasonal change in feeding patterns was a switch from a feeding system based on cut-and-carry grasses under monsoon conditions to crop residue-based diets during the dry season. In order to allow the consequences of this seasonality for the utilisation of feed resources on the study farms to be assessed, values of a "feed fluctuation index" (FFI) were calculated for each monitoring visit to a farm:

$$\text{Feed Fluctuation Index (FFI)} = \frac{\sum_{(1..n)} \left| Q_{f,v} - Q_{f,v-1} \right|}{Q_{f,v-1}} \times 100$$

for feed types, f = 1 .. n where:

$Q_{f,v}$ = quantity (kg) of feed f offered during monitoring visit v

The FFI was used, principally, to identify transition periods during which farmers were changing from the monsoon pattern of feed use to the dry season pattern and *vice versa*. The FFI aggregated differences between consecutive visits in both the type and quantity of feeds used. Thus, the largest FFIs indicated the most marked changes in feed composition which, it was surmised, would occur during a transition period and could, therefore, be used to represent a point of seasonal changeover in the feeding pattern. The application of the FFI in identifying changes in feeding patterns associated with seasons is illustrated by Figure 1b. The demarcation of seasons achieved by applying the FFI to the data for each farm was used to generate season (first monsoon *vs*. dry season *vs*. second monsoon) as a further, three-level *stratum*. In order to investigate the stability of feeding practices in the shorter term, FFIs were also used to evaluate the effects of the three principal factors on changes, from visit-to-visit, in the composition of feed categories within the feeds collected.

Participating Farmers

Thirty two farmers (eight from each site, representing 14 *Rai / Limbu* and 18 *Chetri / Brahmin* households) agreed to participate in the study. Over the fifteen months during which data were collected, three farmers (one from *Angdim*, one from *Jirikhimti* and one from *Phakchamara*) left their farms, breaking up their livestock holdings, in order to migrate to other areas. Data recorded at another farm in *Phakchamara* were judged unreliable as the enumerator experienced difficulties recording the unusually high rates of animal turnover that formed part of the farmer's management regime. Consequently, the interpretation of the study reported here is based on data recorded on 28 farms. Of these, seven were at *Angdim*, eight at *Ankhisalla*, seven at *Jirikhimti* and six at *Phakchamara*. Thirteen of the farmers belonged to *Rai / Limbu* ethnic groups and 15 were *Chetri / Brahmin*.

Data Collection

The study period encompassed two monsoon seasons (June - September, 1993 and June - September, 1994) and one winter / dry season (October, 1993 - May, 1994).

Monitoring Visits

Data were collected from the farms at the four study sites by one of four enumerators based at each site. All data collection was based around a series of monitoring visits. Each farm received a monitoring visit at intervals of approximately 14 days giving a total of 32 sequential observations for each variable from each of the participating farms. Each visit started at approximately 06.00hours (h), coinciding with the first feeding events of the day, and was terminated after the final feeding event, usually at around 17.00h. During the course of each visit, a complete record was made of feeding patterns for the day, of changes in the structure of the livestock holding since the previous visit and of the bodyweights and productive outputs of individual animals.

Livestock Holding Structures and Estimation of Bodyweight

Changes in the structure of ruminant livestock holdings were recorded throughout the study. These included sales and purchases, births and deaths and temporary exits and entries. A number of temporary transfers or exchanges between neighbouring farmers were recorded, particularly with cows and oxen. These generally involved the removal of an animal during a time of perceived feed shortage and its return when pressure on feed resources was reduced. *Rai / Limbu* farmers also keep pigs. However, herds are generally small (only one or two mature animals) and share few common feed resources with ruminant livestock. A consideration of pig feeding practices was, therefore, excluded from the current study.

Estimates of the bodyweights of large ruminants (buffalo, and cattle) were made by weighband (Dalton Supplies Ltd, United Kingdom). Bodyweights of goats were measured directly using a cradle sling attached to a suspended spring balance (Salter Ltd, United Kingdom) with a capacity of 50kg. Some farmers were reluctant to allow pregnant animals to be weighed in this way. In these cases, the equation of Yazman (1987), derived from measurements on the local, Nepali goat, was used:

$$\text{Bodyweight (BW)} = LG^2 / 10500$$

where:

L = body length (cm)

G = heart girth (cm)

A series of comparisons of the predictions of this equation with measured body weights of goats on the study farms indicated errors of less than 10% (Thorne, 1993).

In order to standardise amongst the different species and classes of animals in the mixed holdings studied, metabolic body weights ($BW^{0.75}$) were calculated.

Cut-and-carry Feeds

The main focus of the study was on the utilisation of feeds that were cut-and-carry in a system based, predominantly, on stall feeding. The data collected to describe these cut-and-carry feeds included quantitative estimates of feed utilisation and basic indicators of nutritive value - dry matter (DM) and crude protein (CP) contents.

Utilisation

The utilisation of feeds was recorded for all the individual feeding events that took place during each monitoring visit. The quantities of individual feeds (prior to any mixing) that were offered to each animal (or group of animals fed together) were measured using the suspended 50kg spring balance. Feeds from forest land and crop terrace risers were generally collected and fed as mixtures of species. In this case, quantities of the mix offered were recorded and species composition estimated from a 1kg sub-sample, examined before the mixture was fed, in order to allow a more accurate estimation of diet composition and the DM and CP supplied. Farmers generally collected any feed refusals (occasionally these were then offered to other animals in the holding). Quantities of refused feeds were measured in the same way as those of offered feeds. Apparent intakes of each feed was then calculated by subtracting the quantity refused from the quantity offered.

Nutritive Value

Information on the DM and CP contents of the feeds observed in use during the course of the study was derived from three sources:

- *Direct determinations of feeds sampled during the course of the study* - Representative, 0.5kg samples of feeds were taken by enumerators during monitoring visits. These were bagged, sealed and returned to the Pakhribas Agricultural Centre (PAC), within three days, for preparation and analysis. DM contents of the fresh samples were measured by reserving 100g of coarsely-ground feed material, drying it at $100 \pm 5\ ^{o}C$ for 48h and re-weighing. The remainder of the sample was oven-dried at $50 \pm 3\ ^{o}C$ for 72h and ground in a heavy-duty, commercial coffee-grinder to pass through a 1mm screen. The resulting material was used for the determination of CP content using the method described by the AOAC (1980).
- *Direct determinations of feeds sampled during the course of other studies conducted by the PAC* - Some of the feeds recorded on the study farms were not sampled as their nutritive values have been documented in other studies conducted at the PAC. Values for DM and CP (determined using the methods described above) were adopted for these feeds.
- *Book values* - For some feeds (< 20), samples from the current study and data from other studies were not available. In these cases, representative estimates of DM and CP contents, taken from the literature (Gohl, 1980; Panday, 1982), have been used.

The Contribution of Grazing

The feeding of livestock associated with the study system is based predominantly on the use of feeds that are cut-and-carry to stalled or tethered animals. However, the preparatory work suggested that, even in the Middle Hills where areas of pasture are usually limited, some farmers considered grazing to be an important, supplementary source of nutrients at certain times of the year,. The precise assessment of intakes at grazing was considered to be beyond the scope of and resources available to the study. However, some indication of the contribution of grazing to nutrient supplies was required so that the extent to which this resource might complement the use cut-and-carry feeds could be assessed. During each farm visit the length of time spent grazing by individual animals in the livestock holding was recorded by the enumerator. These data were used to derive a quantitative, grazing index (GI) for each visit to a farm:

$$\text{Grazing Index (GI)} = \Sigma_{(1\ ..\ n)}\, W^{0.75}T$$

for animals 1 .. n where:

W = bodyweight of A (kg)

T = time spent at pasture (hours / day)

The GI was used, on a comparative basis only, to evaluate the effects of the main factors and their interactions on the potential contribution of grazing to the overall availability of feed resources on farms in the study area.

Statistical Analyses

All statistical analyses were conducted using the standard directives and library procedures provided by Genstat 5, release 3.2 (NAG, 1995).

The effects of the main factors and their interactions on the values of the measured and derived variables in the data set were evaluated using a variance components analysis executed with Genstat's REML directive. This allowed the effects of unbalanced factors to be evaluated within a multi-factorial framework, and variances within and amongst farms to be compared.

With the exception of the data describing herd structures, categorical data (e.g. counts of the different feeds observed in use) were treated in the same way as ordinal variables. The large number of observations in the study allowed the assumption that the distribution of these variables would not differ significantly from normality. Application of the more powerful tests indicated that this was the case. Factor effects within the herd data were evaluated using χ^2 tests for independent samples.

RESULTS

Size and Structure of Livestock Holdings

Livestock holdings on the study farms at all sites comprised buffalo, breeding cattle, oxen and goats in varying proportions. Considerable variation was observed amongst the study farms in the sizes of livestock holdings (in terms of total $BW^{0.75}$) and the numbers of each class of livestock found in them at a particular time (Table 1).

Some of the observed variation in the sizes of the livestock holdings studied could be attributed to the main factors examined. Mean holding sizes were similar at all sites. However, small but significant differences were observed amongst sites in the patterns of seasonal changes in holding size (Figure 2). With the exception of *Jirikhimti*, where the mean holding size differed little between the monsoons and the dry season, total holding $BW^{0.75}$ was generally higher during the dry season than during the monsoons ($P < 0.001$).

Holding size was also affected by the ethnic group of the farm household ($P < 0.05$) with *Chetri / Brahmin* farmers keeping larger holdings (mean $BW^{0.75}$ = 263.7; SE_M = 24.1) than *Rai / Limbu* farmers (mean $BW^{0.75}$ = 213.5). This difference could be accounted for partly by a significant reduction ($P < 0.001$) in holding sizes that was observed on *Rai / Limbu* farms during the second monsoon whilst *Chetri / Brahmin* farmers maintained their larger holdings at a relatively constant size throughout the study.

Significant differences in the initial structures of the livestock holdings kept by the two ethnic groups were also observed (Figure 3). *Rai / Limbu* farmers tended to keep more cattle than *Chetri / Brahmin* farmers ($P < 0.01$) whilst *Chetri / Brahmin* farmers kept more buffalo ($P < 0.05$) and oxen ($P < 0.05$) in their holdings. The ownership of buffalo amongst *Rai / Limbu* farmers appeared to be concentrated at *Angdim* and *Ankhisalla*. No significant differences were observed between farmers of different ethnic groups in the numbers of goats kept or in the ownership of improved cattle (Jersey X) or buffalo (Murrah X). No evidence was found of differences in the species composition of livestock holdings or in the use of improved animals amongst sites.

Seasonal Patterns in the Collection of Feed Resources

Analysis of the FFI data confirmed the expected changes in feed composition with the changes in seasons. A switch from the grass-based feeding practices associated with the monsoon season to the crop residue-based practices of the dry season was observed on all farms over a 65 day period between October and December of 1993. No significant difference in the mean date on which this switch was made was observed between Rai / Limbu and *Chetri / Brahmin* farms. However, farmers from *Ankhisalla* appeared to adopt dry season feeding practices almost a month later (24 days; $SE_M = 9.4$ days) than farmers at the other three sites ($P < 0.01$). No significant differences were observed between the two ethnic groups or amongst the four sites in the timing of the return to monsoon feeding practices, which occurred during early June, 1994 on the majority of farms. As a result of the longer period during which they used grass-based diets during the first monsoon, farmers from *Ankhisalla* used the crop residue-based, dry season feeding system for approximately 40 days less than farmers at the other sites ($P < 0.05$).

Cut and Carry Feeds

The Range of Feeds Collected

During the course of the study, a total of 258 different feeds were recorded in the material collected for feeding animals on the 28 farms for which data were analysed. It proved possible to differentiate these into eight categories **-** grasses, dry crop residues, tree fodder, green crop residues, concentrates (e.g brewing residues, legume haulms and oilseed meals, considered by farmers to provide a concentrated source of supplementary nutrients), broad-leaved herbaceous plants, vegetables and vegetable crop residues. The distribution of the individual feeds recorded between these categories and the mean levels of collection of each are, presented in Table 2.

Grasses was the most diverse of the eight feed categories and also contributed the highest proportion (almost 50%) of the DM collected. Dry crop residues were second in importance to the grasses, in terms of DM collected, contributing around 25% of the feeds collected. Tree fodder and green crop residues both contributed approximately 10% of the total DM collected. However, whilst only seven different types of green crop residues were observed in use, 60 different types of tree fodder were recorded across the 28 farms.

Nutritional Characteristics of the Collected Feeds

Differences in the mean DM and CP contents of the eight feed categories and the variability within each category are illustrated in Figure 4. Mean DM contents ranged from 148 g / kg for vegetables to 717 g / kg in concentrates. Mean CP contents were lowest in dry crop residues (73 g / kg DM) and highest in vegetable crop residues (164 g / kg DM). However, the variation in composition within some feed categories (DM in concentrates; CP in grasses, vegetables and vegetable crop residues) was almost as large as the variation across all categories. There was also evidence of significant differences in mean DM and CP contents for individual feed categories that could be attributed to the effects of the main factors. These effects are summarised in Table 3.

Factors Affecting the Composition of Cut-and-carry Feeds

Feed Diversity

Chetri / Brahmin farmers generally appeared to make use of a wider range of feeds than *Rai / Limbu* farmers. This was reflected by the larger number of individual feeds (8.1 *vs* 5.9; $P < 0.001$; SE_M = 0.65) and the wider representation of the eight feed categories (4.6 *vs* 3.5; $P < 0.001$; $SE_M = 0.49$) observed in the material collected for use on *Chetri / Brahmin* farms.

No significant effects of site were observed on diversity in the use of individual feeds. However, more feed categories were represented ($P < 0.05$, mean $SE_M = 0.43$) amongst the individual feeds collected on farms at *Angdim* (4.3) and *Jirikhimti* (4.5) than at *Ankhisalla* (3.8) and *Phakchamara* (3.6).

Highly significant effects of season ($P < 0.001$) on both the number of feeds collected and categories that they represented were observed. The number of feed categories represented in the collected feed was similar during both monsoon seasons but farmers appeared to collect feeds from more categories during the dry season. In contrast, a significant reduction in the range of *individual* feeds collected was observed with the onset of the dry season. Overall, there did not appear to be a return to the use of a wider range of individual feeds at the onset of the second monsoon,. However, a significant interaction between site and season ($P < 0.001$) indicated that this did, in fact, occur on farms at *Angdim* and *Jirikhimti*.. A significant interaction between site and season ($P < 0.001$) was also observed in the number of feed categories represented. This appeared to be accounted for largely by relatively small changes in the diversity of feed use over all three seasons at *Phakchamara* .

Proportional Composition

There was no evidence of differences between *Rai / Limbu* and *Chetri / Brahmin* farmers in the relative proportions of each feed category collected.

Significant ($P < 0.05$) effects of site on proportional composition were restricted to differences in the proportions of concentrates, and the three categories of crop residues (dry, green and vegetable) in the collected feed (Table 4). Greater use was made of concentrate at *Angdim* and *Phakchamara* than at *Ankhisalla* or *Jirikhimti*. However, this difference did not appear to represent any consistent attempt to use concentrate to compensate for the poor quality of crop residues as *Phakchamara* farmers collected the highest levels of dry crop residues whilst *Angdim* farmers used the smallest. Farmers at *Angdim* and *Jirikhimti* used larger proportions of green crop residues than those at *Ankhisalla* and *Phakchamara*. Vegetable crop residues formed only a small proportion of the total feed collected at all sites. However, the use of these feeds appeared to be particularly limited at *Jirikhimti* and *Phakchamara*.

Figure 5 illustrates the general pattern of seasonal changes in the composition, by feed category, of collected feeds. With the exception of green crop residues, significant differences ($P < 0.05$ - $P < 0.001$) were observed amongst seasons in the proportions of each feed category collected by farmers.

During the monsoon season, the collected feed comprised, on average, of 600 - 650 g / kg as fed, grasses compared with 500 g / kg as fed, crop residues during the dry season. Increases, observed during the dry season, in the proportion of tree fodder collected and, to a lesser extent, the proportions of green crop residues and concentrate used were associated with this change from the use of grass to the use of crop residues as the main, basal feed. Over the study period as a whole, these five categories of feed represented approximately 940 g / kg as fed of the total, fresh feed collected.

Seasonal differences in the proportions of all feed categories collected (with the exception of vegetables and vegetable crop residues) were significantly affected by site ($P < 0.001$). The more noteworthy of these interactions are summarised in Figure 6. Farmers at *Phakchamara* used large proportions of grasses during the second monsoon in comparison with farmers at the other sites where proportions were generally similar during both monsoon seasons. However, farmers at *Ankhisalla* collected more than twice the proportion of cut grasses during the dry season than farmers at any of the other three sites. The proportion of dry crop residues in the feed collected by farmers at *Phakchamara* during the dry season was higher than at the other sites where levels of use were similar. The proportion of tree fodder was low in the feed collected by farmers at all sites during the two monsoon seasons. However, considerable variation was observed in proportion used during the dry season. Amongst sites, the greatest use of tree fodder was made by farmers at *Ankhisalla* where the porportion in the collected feeds (207 g / kg as fed) was almost double that in feeds collected by farmers at *Angdim* (109 g / kg as fed).

Visit-to-visit Variation

Calculated FFIs indicated that there were significant differences ($P < 0.01$) between *Rai / Limbu* and *Chetri / Brahmin* farms and between the monsoon and dry seasons ($P < 0.001$) in the extent to which the proportions of different feed categories amongst the feeds collected varied from one visit to the next. Overall, FFIs were larger and, therefore, visit-to-visit variation in the composition of collected feeds was greater during the dry season (77.3) than during the first (63.7) or second (64.8) monsoons (mean $SE_M = 3.3$). However, a significant interaction between ethnic group and season ($P < 0.05$) indicated that seasonality in FFIs was due to the activities of *Rai / Limbu* farmers only and that variation in the composition of collected feeds on *Chetri / Brahmin* farms was similar amongst all three seasons.

The Contribution of Grazing

The contribution of grazing to the feed resources available to animals on the study farms was distinctly seasonal in nature ($P < 0.001$). Farmers at all sites (with the possible exception of *Phakchamara*) made the greatest use of grazing during the dry season (Figure 7). However, differences in grazing indices between monsoon and dry seasons were not consistent amongst sites ($P < 0.05$). Farmers at *Angdim* and *Ankhisalla* appeared to make significant use of grazing resources during monsoons as well as during the dry season whilst farmers at *Jirikhimti* and *Phakchamara* generally made minimal use of grazing resources during the wetter months.

DISCUSSION

Size and Structure of Livestock Holdings

Differences amongst the farms studied in livestock holding sizes were considerable. The combined $BW^{0.75}$ of the animals in the largest holding was more than five times that of those in the smallest. Clearly, large livestock holdings require more feed than small ones if similar levels of performance are to be achieved. Therefore, systematic differences in the size and structure of livestock holdings ought, in part, to reflect access to and the ability to utilise feed resources.

Under conditions of seasonally-fluctuating feed supplies, deliberately changing the size or structure of the livestock holding with season might allow farmers to cope more effectively with feed shortages. However, there was no evidence that farmers participating in the current study did so. In fact, holding sizes were found to be slightly larger (in terms of $BW^{0.75}$) during the dry season although this effect was small and probably only reflected seasonal patterns of bodyweight change in the holding or seasonal patterns of calving. This observation is, perhaps, not surprising as adopting such a strategy would present numerous practical difficulties. Periodic, large changes in holdings sizes would prevent individual farmers from maintaining a steady supply of livestock products for the farm household and the continuity of income from off-farm sales. Such changes would also distort local markets for replacement animals making disposal and restocking a difficult and expensive process. Therefore, sales of animals are likely to be restricted to planned disposals or to take place in response to extreme hardship as described by Nabarro *et al* (1989). The latter appears to have been the case with one of the participating farmers who dropped out of the study after seven months.

The holdings of *Rai / Limbu* farmers were smaller, in terms of $BW^{0.75}$, than those of *Chetri / Brahmin* farmers reflecting perceptions of the more serious resource constraints experienced by the former. This difference was also observed in survey of 1341 farmers in the region (Gurung *et al*, 1989), including several at *Ankhisalla* and *Angdim* , and appeared to be related, in part at least, to a difference in the sizes of the land-holdings of the two ethnic groups. Data from the farm characterisation survey (Thorne and Gurung, unpublished data) indicated that, across the four sites, the average size of *Rai / Limbu* land-holdings (50 *ropani*), was significantly smaller ($P < 0.05$, mean $SE_M = 4.3$) than that of *Chetri / Brahmin* holdings (35 *ropani*) where one *ropani* is a local measure of land area equivalent to 0.05 hectares. The same dataset also suggested differences in land holding types; *Rai / Limbu* farmers having a smaller proportion of the irrigated *khet* land on which rice (and rice straw) is produced than *Chetri / Brahmin* farmers. These differences may be expected to influence the availability of on-farm feed resources, in particular the quantities and relative availability of different types crop residues. Available information suggests that other factors may also be significant in determining holding size. Private ownership of and common-property access to other resources such as forests for fodder collection is probably not evenly distributed between the two ethnic groups (Campbell *et al*, 1990). Differences in the availability of labour for feeding and general care of animals may also affect the size of holding that can be managed effectively, although interviews with participants from both ethnic groups suggested that this was not so (Thorne, 1993). Farmers generally indicated that the most problematic months for labour availability were June and July but that shortages of on-farm labour could be overcome by hiring off-farm assistance.

The species composition of livestock holdings also appeared to be affected by the ethnic group of the farm household with *Rai / Limbu* farmers keeping fewer buffalo and oxen but more cattle than *Chetri / Brahmin* farmers. Buffalo are highly valued in the Eastern Hills of Nepal because of their relatively high yields of milk that is rich in butterfat and for manure for compost making. However, they are also more expensive to purchase and require more feed than cattle. For relatively resource-poor farmers, substituting cattle for buffalo might allow production of milk and manure at a lower level of risk. Despite also producing significant quantities of manure, oxen are generally considered by farmers to be unproductive outside working periods. Whilst reducing numbers of oxen may present problems in meeting work schedules, it may be an attractive option where holding sizes are seriously constrained by resource availability. Interviews with farmers (belonging to both ethnic groups) indicated that this strategy was actively considered by many (Thorne, 1993).

Clearly a number of factors may be expected to affect the size and composition of individual livestock holdings. Nevertheless, it is worth noting the observations of Gatenby *et al* (1990) who found that a sample of 275 farmers surveyed were able to specify nine distinct reasons for keeping buffalo and ten for keeping cattle. With this level of complexity in the multiple objectives of farmers keeping livestock, there are unlikely to be simple interpretations of the differences observed in holding structures amongst farms.

Seasonal Patterns in the Collection of Feed Resources

The existence of seasonality in feeding practices described by other authors (e.g. Conlin and Falk, 1979; Gatenby *et al*, 1989) was confirmed in the current study. Clear peaks in FFIs corresponding with the beginning and the end of the dry season were identifiable on all farms (e.g. Figure 1b). As the FFI measured changes taking place between successive visits (at intervals of only two weeks), the existence of these peaks indicated that seasonal changes in the composition of collected feed resources occurred rapidly rather than gradually on individual farms. Distinct changes from dry season to monsoon feeding practices are to be expected as growth flushes of new fodder occur rapidly with the onset of the rains. That changes occurring with the end of the first monsoon season appeared to be equally distinct, both on individual farms and amongst farms (with the exception of those at *Ankhisalla*), suggests that farmers exercise considerable care and skill in balancing animal numbers with the availability of seasonally-fluctuating feed resources. This is further implied by the lack of an observed difference between *Rai / Limbu* and *Chetri / Brahmin* farmers in the timing of seasonal changes in feeding practices. Although the former may, generally, keep fewer animals, the approaches of both groups to balancing animal numbers with feed resources would appear to be similar.

Evidence of the existence of factor effects on the timing of changes in the composition of collected feed resources was limited to an apparently later return to dry season feeding practices on the farms studied at *Ankhisalla*.. This observation was surprising and difficult to explain as *Ankhisalla* was perceived as a relatively dry area by farmers and local researchers. Data from the initial characterisation survey (Thorne and Gurung, unpublished data) did not suggest that farmers at *Ankhisalla* had greater access to on-farm fodder resources and no differences in levels of feeding were observed amongst the four sites during monsoon seasons (Thorne and Gurung, unpublished data). Farmers at *Ankhisalla* appeared to make greater use of grazing during the monsoon season than farmers at *Jirikhimti* and *Phakchamara* which may have had a sparing effect on the use of on-farm feed resources. However, farmers at *Angdim* made even greater use of grazing than those at *Ankhisalla*.

Cut-and-carry Feeds

The Range of Feeds Collected

The range of feeds recorded across the participating farms during the course of the study is striking. The extent of this (258 different feeds observed) is not inconsistent with the findings of Gatenby *et al* (1989) who recorded 37 different feeds used for buffalo in a less sensitive, static survey. At first sight, this level of variation would appear to complicate the analysis of feed resource utilisation and the development of improved component feeding strategies to an almost impossible extent. However, a number of simplifying assumptions may be made.

For example, individual grasses (the most diverse category observed in this study) are rarely fed in isolation but in mixtures. Whilst farmers are able to identify some individual components of these mixtures, others were not individually named suggesting that there was little perception of large differences in their nutritive values. Furthermore, the mixing of feeds in this way, tends to produce a dietary component with nutritional characteristics approaching the mean for that category. Therefore, despite the wide variation in chemical composition observed and discussed below, aggregating individual feeds into categories may not necessarily distort interpretation to a great extent. Nevertheless, such an approach should be employed with care, particularly where an individual feed may markedly influence animal responses as might be occur when anti-nutritive factors are present. This might apply with the second most diverse category observed, tree fodder, and there is strong evidence that farmers appreciate the extent of variation in nutritive value amongst different types of tree fodder (Thapa *et al*, in press) and are able to discriminate them effectively on that basis (Thorne *et al*, in review) and plan feeding strategies accordingly.

Nutritional Characteristics of the Collected Feeds

Interpretation of the data on the nutritional characteristics of the collected feeds is somewhat compromised by the piecemeal approach that was necessary in order to estimate DM and CP compositions. However, it is apparent that, in general terms, the wide range of feeds recorded was reflected in a similarly wide range in their compositions.

Interpretation of differences in the DM and CP contents of the different feed categories due to site, ethnic group and season is, again, compromised by the approach taken in estimating compositions. Thus, these differences may only be attributed to differences in compositions *amongst* individual feeds used at different sites, by different ethnic groups or during different seasons and not to variation *within* those feeds. The latter is likely to be of particular significance in relation to seasonal effects. Nevertheless, a number of potentially, interesting observations may be made.

Overall, there appears to be little evidence of effects of farmer ethnic group on the mean chemical compositions of the different feed categories used. This would suggest that any differences between *Rai / Limbu* and *Chetri / Brahmin* farmers in their respective abilities to supply nutrients to their animals are likely to result from more restricted feed availability than from access to better quality feed (at least in terms of energy and protein supply). Therefore, it might be expected that, provided the smaller holding sizes maintained by *Rai / Limbu* farmers are adequate to compensate for any relative restrictions that they might experience in feed supplies, little difference should be observed between the two groups in nutrient supply and consequent animal performance. Differences in DM and CP contents amongst sites and between seasons were more widely observed in the different feed categories (although the nature of these effects were not consistent amongst categories). However, the implication is that effects of feed quality might be expected to represent a component of any factor effects that are observed on nutrient supplies and animal performance.

These issues are considered in greater depth in the context of DM and protein supplies across livestock holdings in a companion paper (Thorne *et al*, this volume).

Factors Affecting the Composition of Cut-and-carry Feeds

Feed Diversity

Observations on the effects of the three main factors on diversity of feed use (i.e. the number of different feeds or types of feed observed during any one observation visit) suggest considerable differences between ethnic groups and amongst sites and seasons in the nature of the feed resources available.

Despite similarities in the DM and CP compositions of the different feed categories collected on *Rai / Limbu* and *Chetri / Brahmin* farms, feed diversity on the farms of the former appeared to be considerably less. This would suggest that *Chetri / Brahmin* farmers have access to a broader base of feed resources. It is possible to speculate on reasons for this but little supporting evidence is available. Differences are likely between the two ethnic groups in the range of crops grown (and therefore the range of crop residues available for feeding); in the availability of labour for more widespread fodder collection; in the extent of access to private forest resources (and possibly grazing land although no differences between grazing use by the two groups were recorded in the current study), and in the extent of adoption of novel, on-farm fodder resources (e.g. tree fodder and forage legumes). There is, however, a likely practical implication of the use of more diverse diets as these are more likely to allow specific nutritional deficiencies to be avoided. Indeed, the observations of Thapa *et al* (in press) would suggest that Nepalese farmers are aware of this principle as they appreciate the benefits of combining different types of tree fodder that they consider to be of different quality.

Similar consequences might be expected from differences in diversity of feed use at the different sites and during the different seasons. The results of the study appear to suggest that, not only are smaller quantities of feed available during the dry season (Gatenby *et al*, 1989), but that these also come from a more restricted range of feed resources (although a more diverse range of feed categories may be represented). The fact that diversity of use of individual feeds does not increase relative to the dry season with the onset of the second monsoon is difficult to interpret. This monsoon (1994) was unusually late in arriving and this may have resulted in unusual collection behaviour by farmers. However, during the last few months of a 15 month study it would be risky to discount the possibility of "enumerator fatigue" contributing to this observation.

Proportional Composition

The general seasonal pattern of feed utilisation observed in the study was expected, with a clearly-defined switch from the use of green feeds during monsoons to dry feeds during the dry seasons. A similar pattern of feed use for buffalo was recorded by Gatenby *et al* (1989). The change from green grasses to dry crop residues as the principal ingredient of diets might be expected to result in a serious decrease in the supply of dietary protein. However, farmers appear to attempt to counteract this by increasing the use of tree fodder, with a relatively high CP content, during the dry season.

Whilst the general seasonal pattern in feed use described above was clearly identifiable, the data presented in Figure 6 illustrate the need for factor effects (in this case the effect of site) to be considered in more detail if this type of information is to be of use in intervention planning. As an example, farmers from *Ankhisalla* appeared to collect more than twice as much tree fodder during the dry season as farmers from *Angdim*.. This would suggest that:

- appropriate strategies for improving dry season feeding are likely to differ between the two sites;
- a potential intervention at *Angdim* might be to encourage the planting of fodder trees on private land.

The feasibility of such a strategy would, of course, require more detailed assessment. Amongst reasons given by farmers for not planting trees on private land, Joshi and Thapa (1992) include a lack of seedlings and insufficient land. Although extension services might readily develop a programme of activities to overcome the former, in areas where the latter is a problem tree planting would probably not represent a practical solution to dry season feed shortages.

Visit-to-visit Variation

The observations on visit-to-visit variation are interesting and would appear to indicate that, despite using feed from fewer categories overall, *Rai / Limbu* farmers still need to alternate amongst feed categories more frequently than *Chetri / Brahmin* farmers during the dry season. In the current study, observations were made at fortnightly intervals but, if they represent a pattern of day-to-day variation as, it has been suggested, may occur in other systems (J. Tanner, personal communication) the implications of this fluctuation might be considerable. To our knowledge, there has been little or no research, appropriate to the smallholder situation, on the consequences of short-term fluctuations in diet composition for rumen function or animal productivity. However, as the rumen is designed to function in a state of responsive, dynamic equilibrium, short-term fluctuations occurring on a day-to-day basis may be expected to compromise efficiency. In the Nepalese context this might conceivably represent another respect in which *Rai / Limbu* farmers may be disadvantaged in comparison with *Chetri / Brahmin* farmers. More generally, the likely implications of such a situation for planning interventions in feeding systems and the development of feeding strategies would appear to make this an important and under-researched area.

The Contribution of Grazing

Extensive use of grazing is a particular feature of higher altitude (above 2100 m.a.s.l.) systems in Nepal where animals may be pastured for up to seven months of the year (Oli, 1985). However, the current study suggests that the use of grazing may not be insignificant at lower altitudes, although there would appear to be considerable differences in the extent to which grazing was either available or used amongst the four study sites. This observation was consistent with farmers perceptions of the utilisation of grazing as a feed resource that were recorded in the initial farm characterisation survey (Thorne and Gurung, unpublished data).

The index used to assess the contribution of grazing did not include any estimate of pasture productivity and nutrient supplies from grazing. However, the fact that farmers were found to be prepared to make a considerable investment of labour in the supervision of grazing would suggest that they perceive tangible benefits from the practice. Obviously, these might include the provision of nutrients to supplement those derived from feeds offered in the stall. The apparent, greater reliance on grazing during the dry season, when the availability of collected feeds is lower (Thorne and Gurung, unpublished data), that was broadly observed at all four sites might also support this contention. However, other factors may also underly this seasonal pattern in grazing indices. During monsoon seasons, conditions on paths become difficult and the movement of animals to pastures may become impractical where the grazing area is a significant distance from the stall. Furthermore, competition for labour is likely to be more intense during the major cropping periods of the monsoon season.

Another potential benefit of grazing animals lies in the possibility of importing nutrients from pasture to cropland (e.g. de Leeuw *et al*, 1995). Given the careful management of manure-compost in the farming systems of the middle hills of Nepal and the value placed on manure from all livestock species (Gatenby *et al*, 1990), this may represent a significant impetus for investing labour in grazing systems.

Conclusions and Methodological Implications

The type of analysis presented in this paper offers a number of potential benefits for the planning of research and extension activities aimed at improving year-round feeding strategies for livestock. The need to evaluate gross differences between farmers occupying different locations or belonging to different categories and the effects of these factors on their existing opportunities (and therefore their ability to assimilate different improvements) would seem to be clear. It is also apparent that solutions to problems of feed resource availability and utilisation may lie within the existing resource base and that a characterisation of this type may assist in identifying such cases.

The major drawback of the approach would appear to lie in the collection, collation and analysis of large quantities of heterogeneous data; a task that has contributed significantly ($P < 0.001$) to the long interval between this study being conducted and its publication date. However, whilst the results presented here were derived from a quantitative data set, most of the information used in support of the discussion points is, in essence, qualitative. Where this is the case, we might expect to be able to use rapid appraisal tools to generate information that could be gathered and handled more simply but be effective in supporting a similar level of analysis. This approach would not be feasible for estimating values for the feed quality parameters used in this study, although evaluations of indigenous farmer knowledge of fodder quality conducted in the study system (Walker *et al*, in review) would suggest that reliable indicators of relative quality based on ranking might be obtained from the farmers themselves.

Uptake of interventions in the feeding systems practiced by smallholder farmers has, generally, been poor. Accumulated evidence suggests that this is largely because new approaches cannot be integrated effectively with existing practices and constraints. If such innovations are to be more appropriate in future, the analysis of existing systems (at the very least at the level of that presented in this paper) will become an essential prerequisite.

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Table 1: *Typical populations of different classes of livestock on the study farms and summary of the variability observed in holding structures and sizes.*

	Mode	Mean	Minimum	Maximum
Numbers of:				
Breeding buffalo	1	1.3	0	4
Growing buffalo	1	1.1	0	3
Breeding cattle	1	1.3	0	4
Growing cattle	2	2.0	0	4
Oxen	1	1.2	0	6
Mature goats	3	3.3	0	8
Growing goats	9	9.7	0	20
Total metabolic bodyweight in holding ($kg^{0.75}$)	-	240.1	70.6	384.9

Table 2: *The distribution, by feed category, of the individual feeds used on study farms during the observation period.*

Feed category	Number of distinct examples recorded during the course of the study	Mean dry matter collected during the study (kg / farm / day)
Grasses	72	12.7
Green crop residues	7	2.6
Broad-leaved herbaceous plants	20	1.0
Vegetables	14	0.1
Vegetable crop residues	24	0.3
Tree Fodder	60	2.9
Dry crop residues	17	7.0
Concentrates	43	1.3
Total	258	27.9

Table 3: *Summary of the main sources of variation in the dry matter and crude protein compositions of the eight feed categories.*

Feed category	Site	Ethnic group	Season
Dry matter			
Grasses	***	*	***
Dry crop residues	***		***
Tree fodder	***		
Green crop residues	**		*
Concentrates	***	***	
Broad-leaved herbaceous plants	*		***
Vegetables			
Vegetable crop residues	***	*	***
Crude protein			
Grasses	***	*	***
Dry crop residues	**		***
Tree fodder		*	**
Green crop residues			***
Concentrates	***		
Broad-leaved herbaceous plants			
Vegetables			
Vegetable crop residues			***

Differences were significant at the 0.05 (*), 0.01 (**) and 0.001 (***) per cent levels of probability.

Table 4: *The effects of site on the proportions (g / kg as fed) of different feed categories in the collected feeds.*

Site	Concentrates	Dry crop residues	Green crop residues	Vegetable crop residues
Angdim	46	159	126	10
Ankhisalla	23	176	65	18
Jirikhimti	29	210	134	4
Phakchamara	51	254	81	4
SE_M	13	52	31	5

Figure 1: *Seasonal patterns in the utilisation of cut-and-carry feed resources (*Chitra Bahadur Sunawar - *Angdim)*.

Figure 2: *The effect of site on seasonal changes in the sizes of livestock holdings on the study farms*.

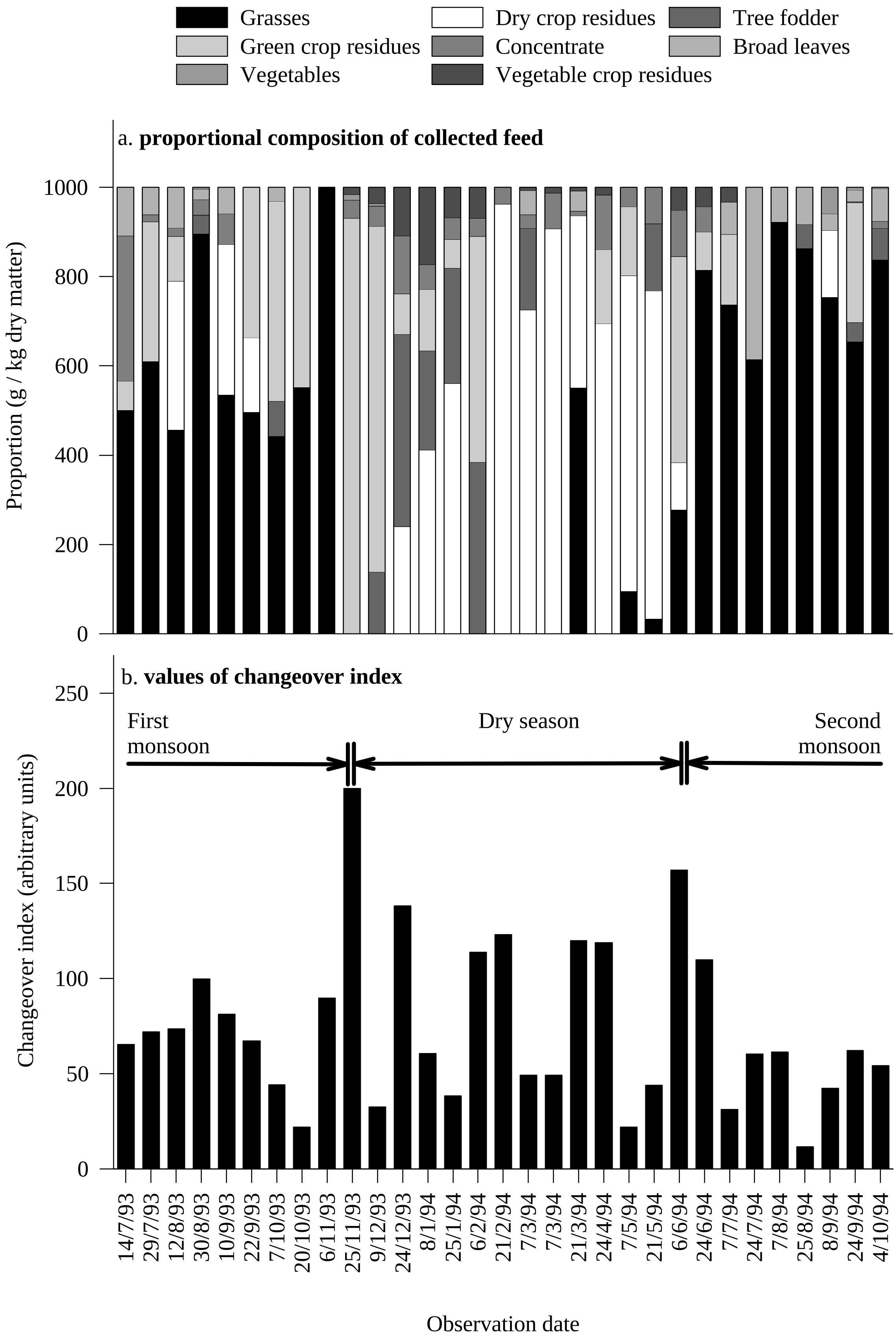
Figure 3: *The effect of ethnic group on the structures of large ruminant holdings on the study farms*.

Figure 4: *Variability in chemical composition and means for the eight feed categories recorded on the study farms (vertical lines = means; boxes = standard deviation; whiskers = 95 per cent of observations; open circles = outlying values).*

Figure 5: *The main effect of season on the proportional composition of collected feed resources on the study farms*.

Figure 6: *The effects of site on seasonal patterns in the use of grasses, tree fodder and crop residues.*

Figure 7: *The effects of site on seasonal patterns in the use of grazing resources to compliment cut-and-carry feeds on the study farms*.


Grasses
Dry crop residues
Tree fodder
Green crop residues
Concentrate
Broad leaves
Vegetables
Vegetable crop residues
a. proportional composition of collected feed
Proportion (g / kg dry matter)
0
200
400
600
800
1000
b. values of changeover index
Changeover index (arbitrary units)
0
50
100
150
200
250
First monsoon
Dry season
Second monsoon
14/7/93
29/7/93
12/8/93
30/8/93
10/9/93
22/9/93
7/10/93
20/10/93
6/11/93
25/11/93
9/12/93
24/12/93
8/1/94
25/1/94
6/2/94
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7/3/94
7/3/94
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6/6/94
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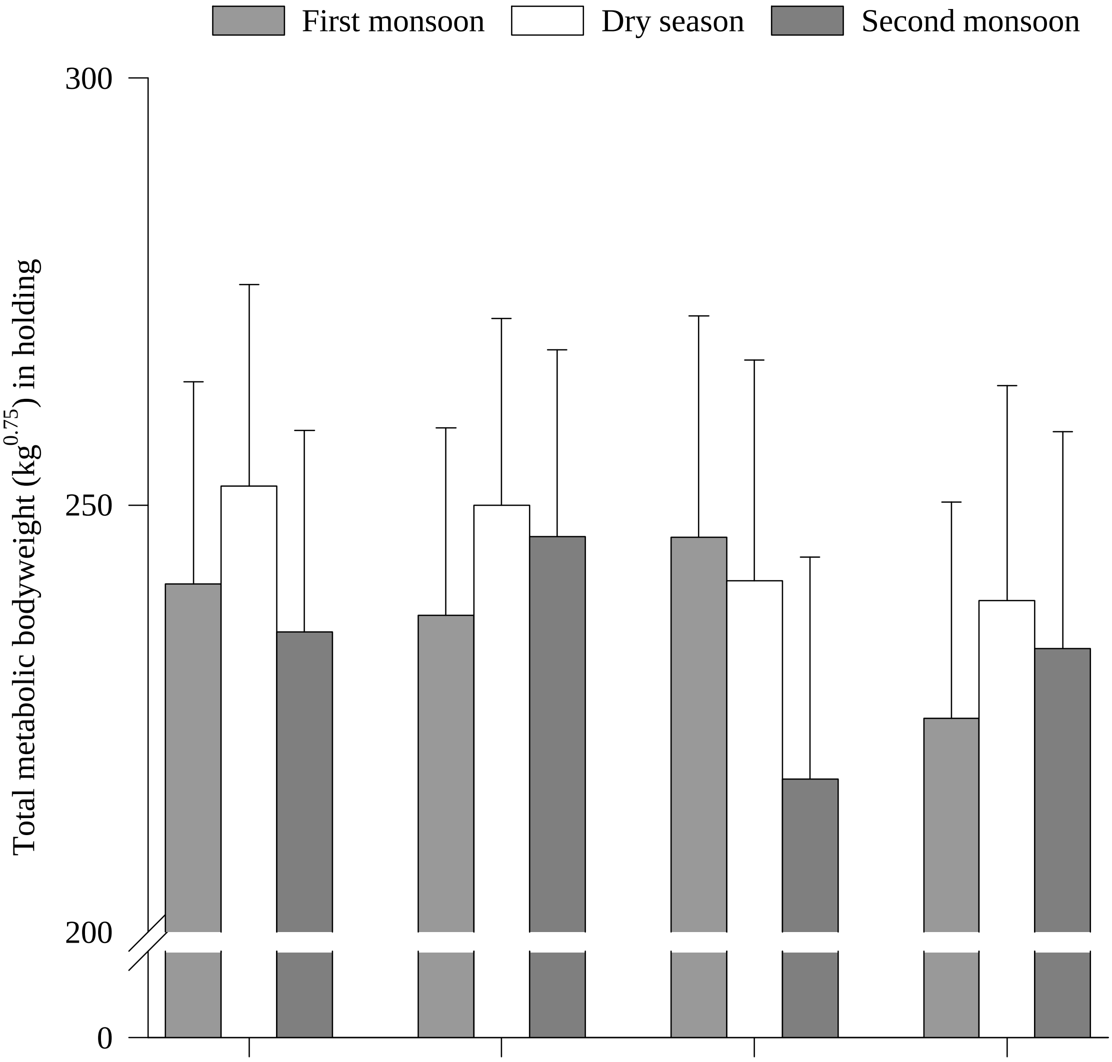
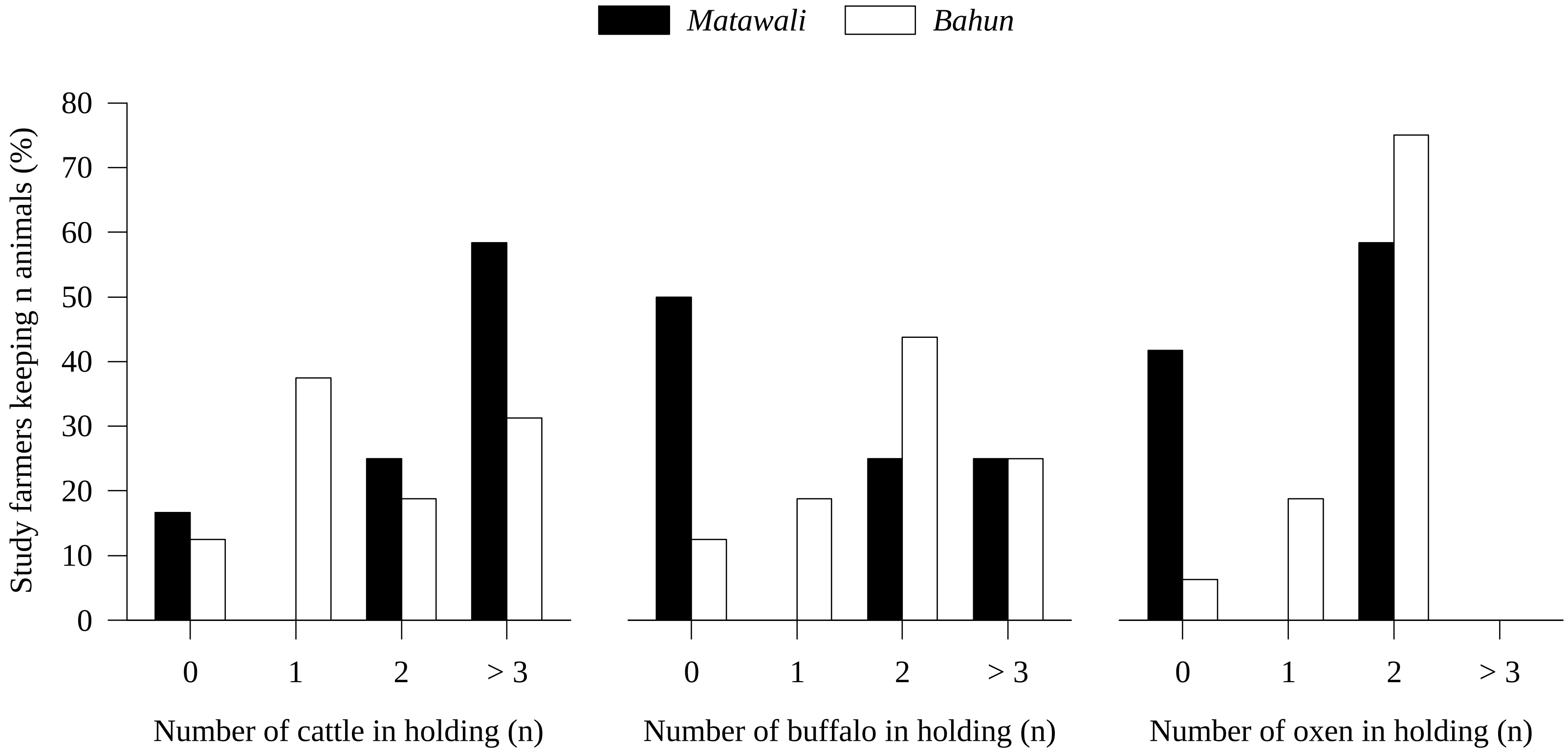
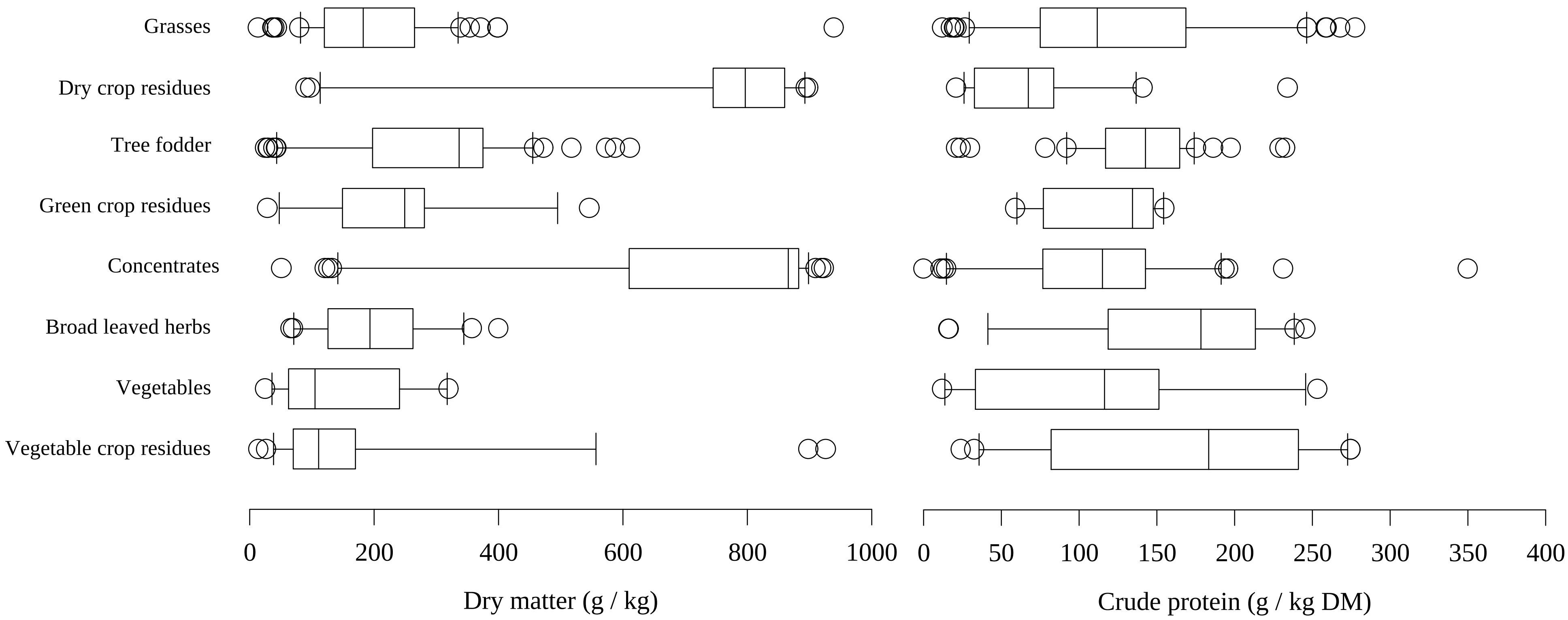
4/10/94
Observation date

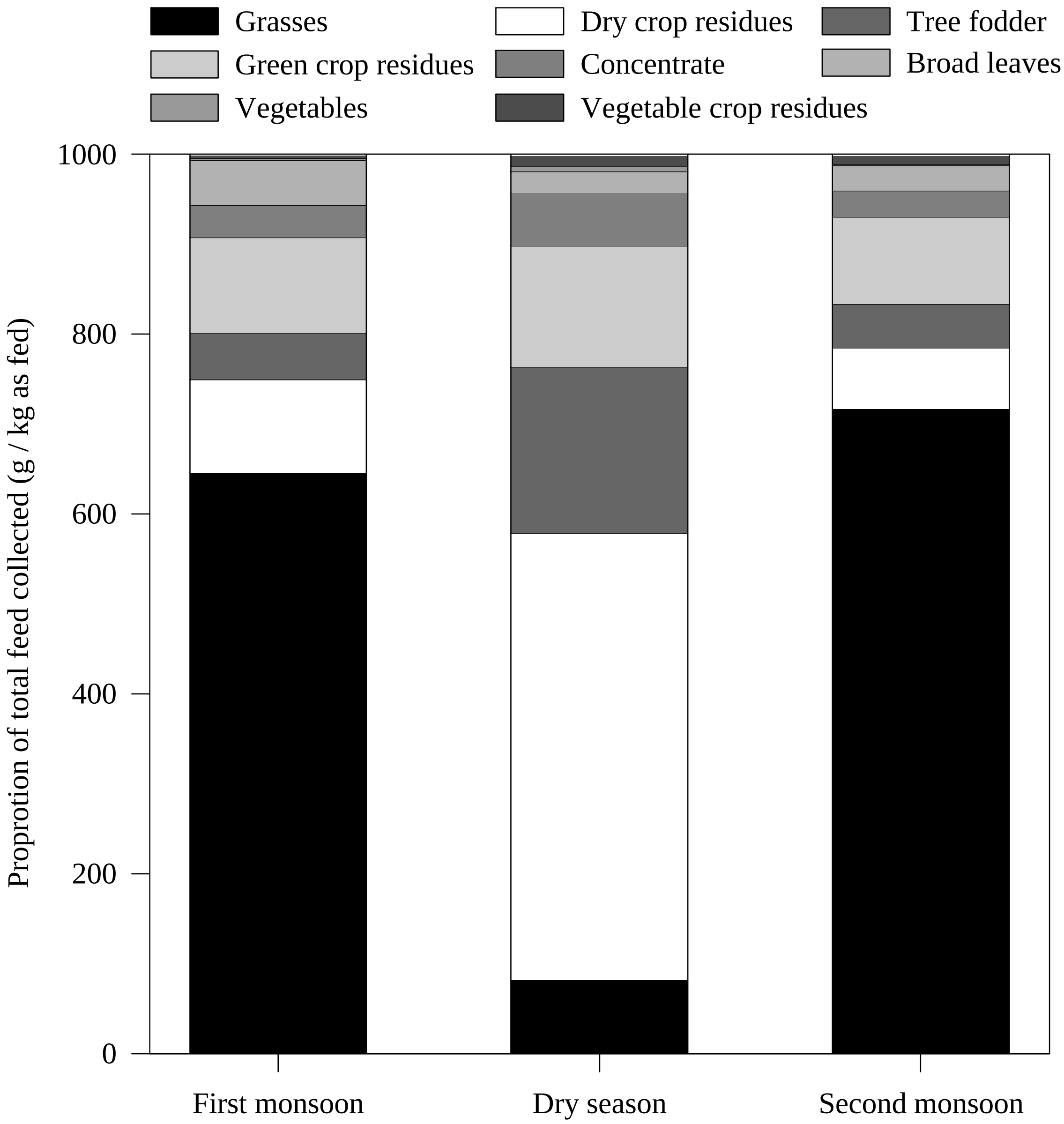


Thorne *et al*: - Figure 2

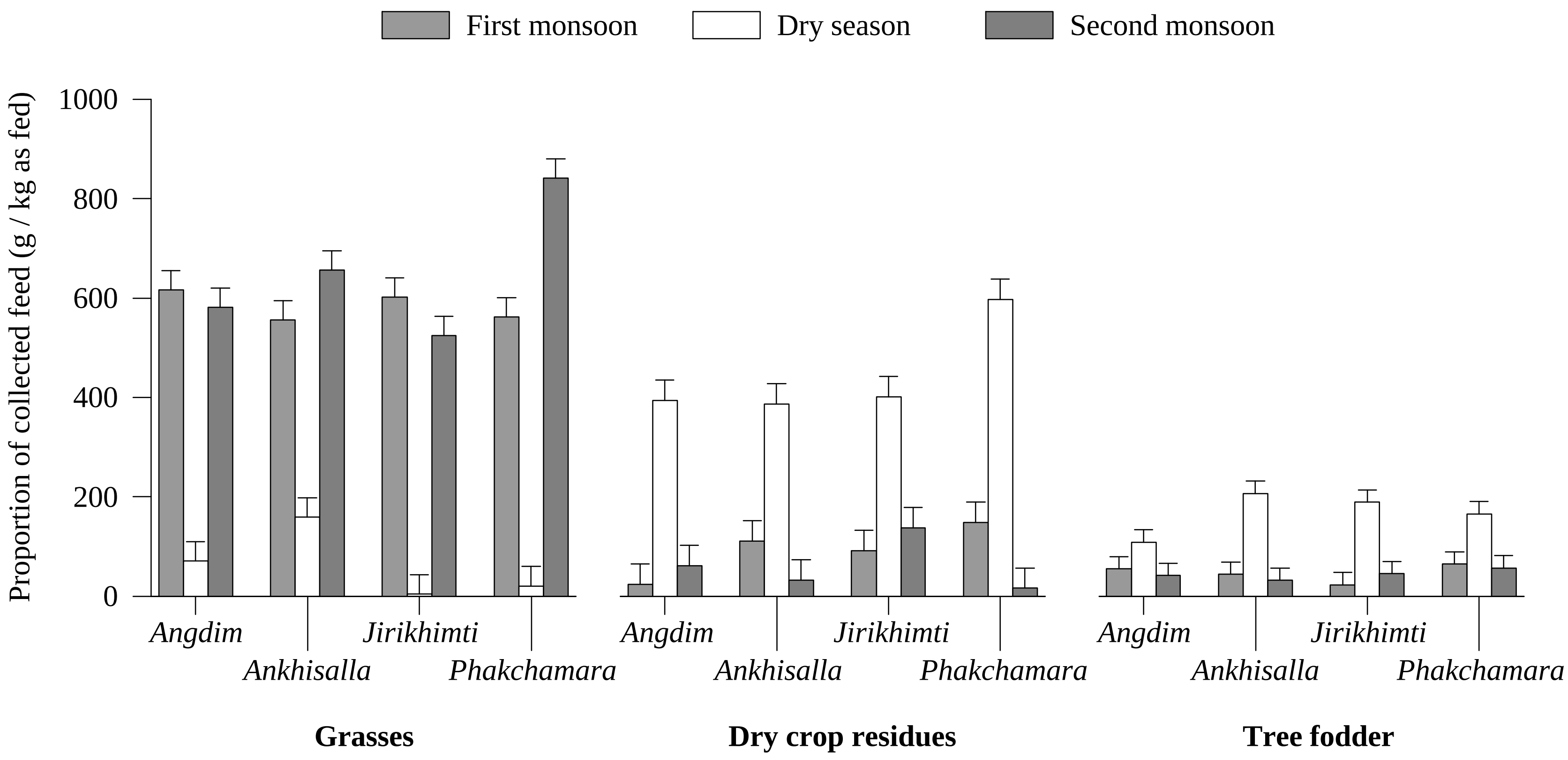


Thorne *et al*: - Figure 3

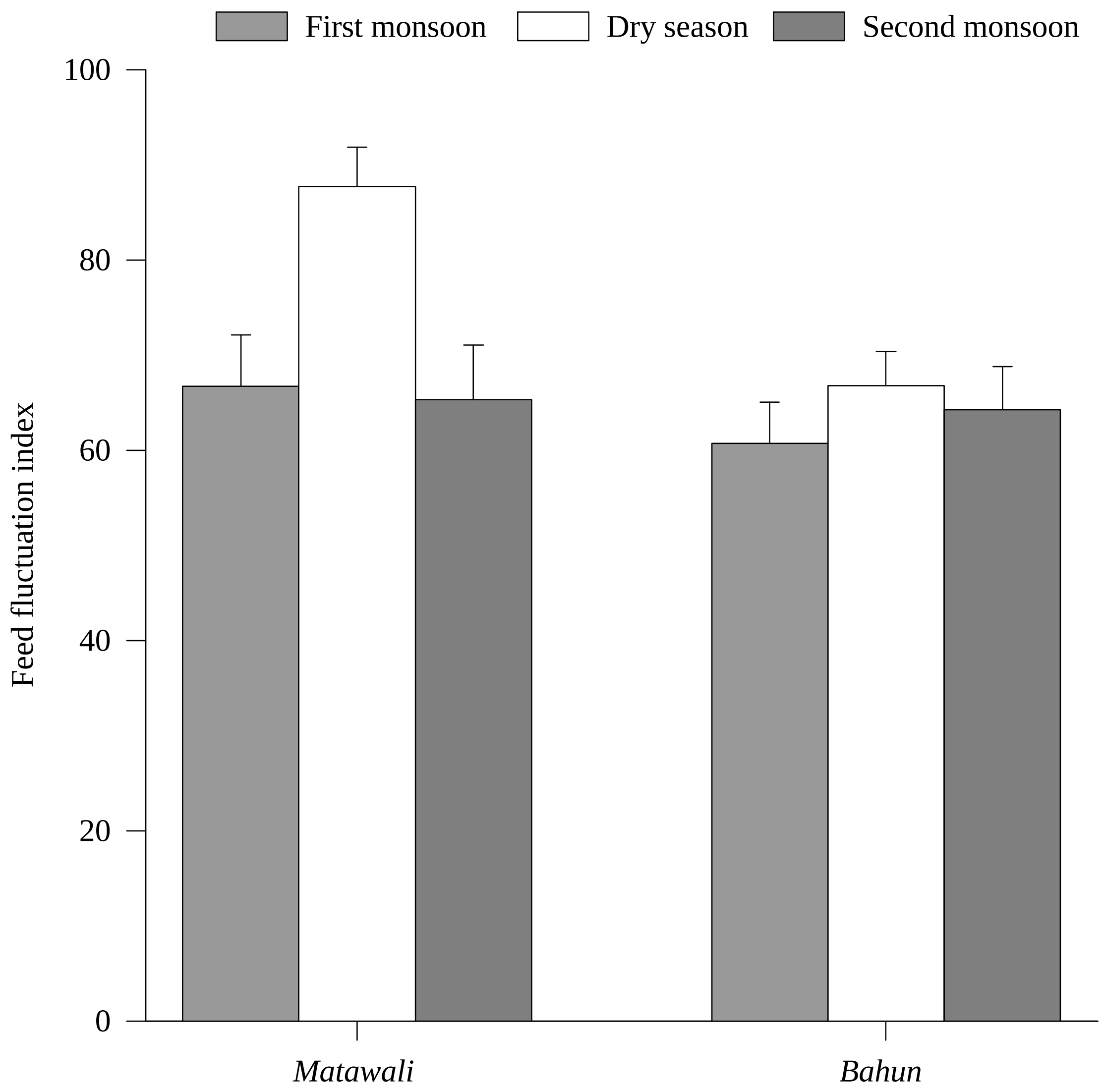

Grasses
Dry crop residues
Tree fodder
Green crop residues
Concentrates
Broad leaved herbs
Vegetables
Vegetable crop residues
0
200
400
600
800
1000
Dry matter (g / kg)
0
50
100
150
200
250
300
350
400
Crude protein (g / kg DM)

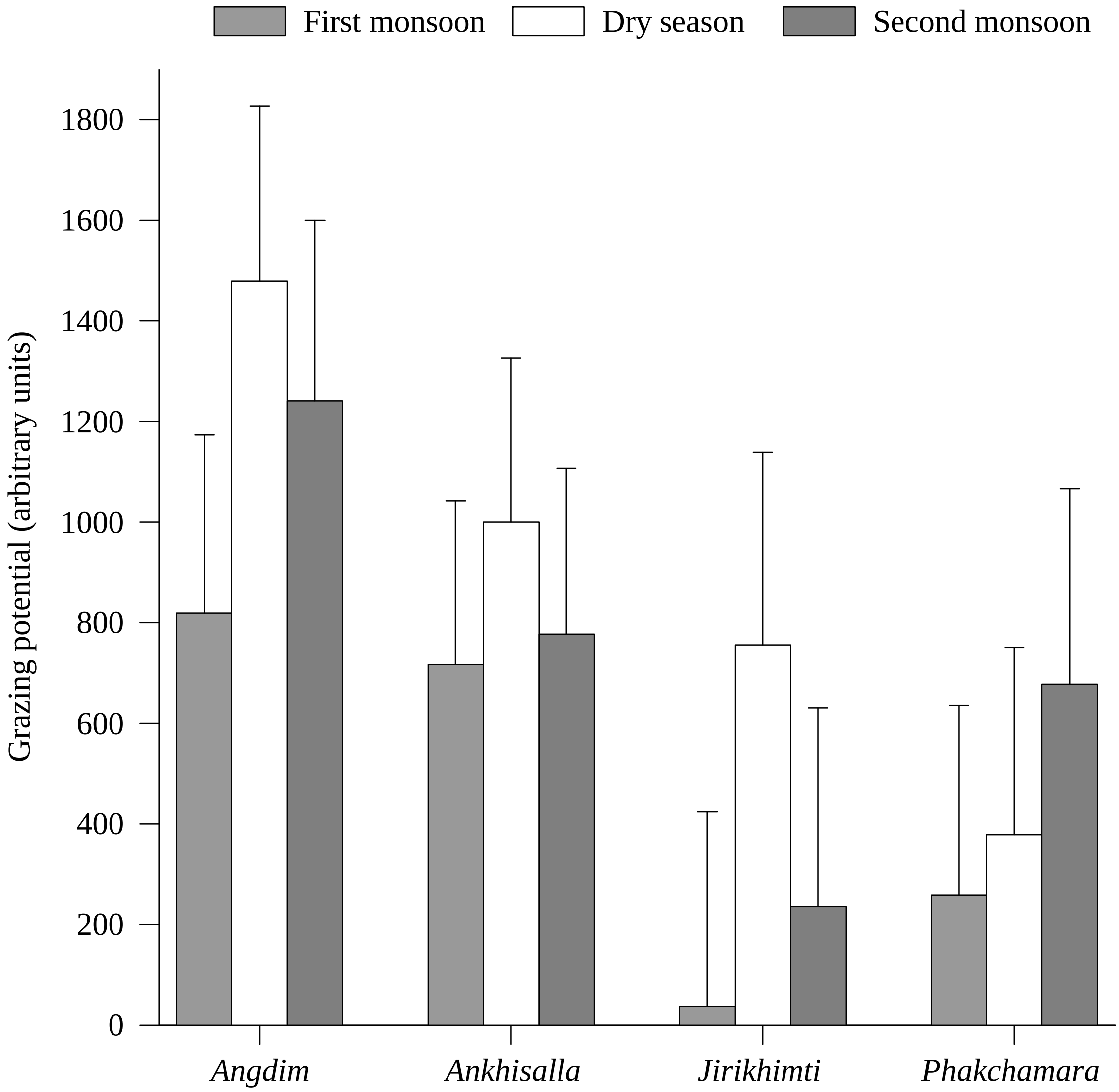


Thorne *et al*: - Figure 5



First monsoon
Dry season
Second monsoon
Proportion of collected feed (g / kg as fed)
1000
800
600
400
200
0
Angdim
Ankhisalla
Jirikhimti
Phakchamara
Angdim
Ankhisalla
Jirikhimti
Phakchamara
Angdim
Ankhisalla
Jirikhimti
Phakchamara
Grasses
Dry crop residues
Tree fodder


First monsoon
Dry season
Second monsoon
Feed fluctuation index
100
80
60
40
20
0
Matawali
Bahun



Thorne *et al*: - Figure 7