COMBINING LOCAL AND SCIENTIFIC KNOWLEDGE ABOUT TREE FODDER EVALUATION AND MANAGEMENT IN THE HILLS OF NEPAL

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A thesis submitted in candidature for the degree of *Philosophiae* Doctor

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August 2004

DECLARATION

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigation except where otherwise stated. Due acknowledgement is made on the following page for any assistance I have received; other sources are identified by explicit references. A bibliography is appended.

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ACKNOWLEDGEMENTS

The research presented in this thesis is an output of the projects jointly funded by the Hill Agricultural Research Project (HARP 148/99) and Department for International Development (R7637, DFID-UK) for the benefit of developing countries. This thesis was supervised by Dr Fergus L. Sinclair of the School of Agricultural & Forest Sciences (SAFS), Dr Peter J. Thorne of the Stirling Thorne Associates and Dr Hussain M. Omed of the Centre for Arid Zone Studies (CAZS). Dr Ioan Ap Dewi of SAFS and Mr Chakra B. Budathoki (Oklahoma State University, USA) provided biometric advice.

Dr Michelle Jones read and commented on all my Chapters. I am extremely thankful for her everlasting willingness to support and the kindness she has shown in many ways. I am also thankful to Mrs Karen Cooper, Ms Jane Lee, Ms Helga Dixon and Ms Emma Youde for administrative support. Mr Jim Doores, Ms Catharine Moss and Mr W. Waliszewski initially commented on my knowledge base. Ms Moss also provided useful tools she created which were helpful to edit and update my knowledge base. My thanks also go to Prof Bob Ørskov and Dr Brenda L. Hector of Maculay Land Use Research Institute for analysis of gas production and Mrs Llinos Hughes of Henfaes for tannin assay of some tree fodder samples. The results formed check samples on analyses of my actual samples in Nepal.

Executive Director of NARC Mr R.N. Sapkota, Mr D. Joshy (former ED, NARC) and Mr H.R. Shrestha, Mr S.B. Panday and Dr N.P. Shrestha of NARC are gratefully acknowledged for their moral support. I am extremely indebted to Mr P.L. Karna (Station Chief); without his encouragement and institutional support this study would not have been possible. Dr Subha N. Mahato (Director General, DLS), Dr K.R. Regmi (former Station Chief, ARS-P), Dr S.B. Mathema (HRP-Manager), Mr Jon Tollervey (former Director PAC) and Shri Laxmi B. Halwai (Dharan) are also duly acknowledged for their moral support.

My due respect and gratitude to the farmers of Dhankuta, Terhathum, Sankhuwasabha and Ilam districts for their invaluable time and contribution that lead to the development of dry season tree fodder knowledge base.

Excellent support received from Mr Chura M. Bhusal, Mr Uddhav P. Wagle, Mr Angsingh Mehera, Mrs Indra M. Gurung, Mr Bir B. Tamang, Mr Shiv N. Mehata, Mr Devendra Budathoki and Mr Craig Thompson (MSc student, SAFS, University of Wales) for their assistance on acquiring farmers' knowledge and conducting fieldwork is highly commendable. Laboratory supports received from Mr Yukti L. Mukhia, Mr Kula N. Mishra, Mr Narendra P. Sah, Mrs Yasoda Basnet, Mr Thahar B. Katuwal, Mr Tej B. Magar and Mr Baburam Thapa are appreciatively acknowledged. Thanks are also due to Mr Narayan Bhandary (Patle), Mr Bhuwan S. Niraula (Fakchamara), Mr Govinda Thapa (Sindhuwa) and Mr Rajendra Bhujel (Mamling) for their assistance in the tedious repeated measurement studies.

Mr Purushottam P. Khatiwada, Dr Madhav P. Aryal, Mr Tulsi P. Poudel, Mr Govinda P. Timilsina, Ramji P Bhattarai, Mrs Niroo Dewan, Mr Bikash Shrestha and Mr Pradhumna Subedi at ARS-Pakhribas are gratefully acknowledged for their support and friendship. Similarly, I am thankful to Mr Juddha P. Bajracharya, DLS and Mr Ananda Parajuli, RDC/UMN, my colleagues Drs Laxman Joshi, Shreeram P. Neopane, Thakur P. Tiwari and Dil P. Sherchan for their support and interest in my research. I take this opportunity to thank collectively all my Nepalese friends (Drs Jwala Bajracharya, Pratap K. Shrestha, Govinda Acharya, Ram B. Prasad and Messers Sajan Shrestha and Bibek Bhatta) and their families in Bangor for respect, generosity and friendship we enjoyed without which we would have suffered from homesickness during our stay. Mrs Sita Acharya wife of Dr Govinda Acharya was a reliable source to update my limited knowledge on use and management of tree fodders in the western mid hills of Nepal. I would also like to thank my colleagues Preecha, Judith, Sirajul, Ronnie, Juan Carlos, Tomás, Antonio, Polly, Neal, Tracey, Siti, Vicky, Hana, Ajay, Animon, Faisal, Wilson, John and Marcos in Bangor for support and friendship.

Finally, the company, love and encouragement I received from my wife Paroo and our children, Akshaya and Akansha in Bangor; my sister and her family and my in-laws in Nepal were the source of inspiration to accomplish my goal.

Summary

This thesis is an investigation of local and scientific knowledge about tree fodders used to supplement livestock diets in Nepal. The study was conducted at five sites: two remote sites with poor accessibility to markets and three sites with good market access in the eastern mid hills of Nepal. On the basis of surveys and repeated measurements, qualitative and quantitative information was derived on nutrient intake, animal productivity, farmland tree fodders and other local feed resources. This study aimed to build on knowledge of tree fodder, to provide a picture of how the farmers manage animals and local feed resources and plan strategies to mitigate fodder shortage in the dry season. The study also critically examined the correspondences between local fodder evaluation methods and evaluation of fodders in scientifically conducted feeding trials.

The relative importance of different fodder resources used in livestock diets (tree fodder, grass, dry roughages and local concentrate) was influenced by a number of factors, most notably season and site. Total daily dry matter intake for large ruminants was high compared to the western standard. Overall intake of nutrients based on laboratory analysis of fodder suggested lower than recommended rates of intake of protein and energy which was especially true in sites with low market accessibility.

In evaluating tree fodder, farmers considered animal factors (palatability, intake, digestibility, nutrient availability, control of animal behaviour) and socio-cultural factors (fodder, firewood, type of manure produced and other household uses), making evaluation of fodder quality complex. The knowledge system of farmers appeared to be crucial in making decisions about the management and use of available fodder particularly during the dry season.

In addition to the *posilopan* (high nutritive value) and *obhanopan* (dry and warm) attributes of fodder, which have been previously recorded by other authors, this study recorded another term, *'adilopan'* (literally duration of appetite satisfaction), which was broadly used in association with the term *obhanopan* when evaluating fodder quality.

The study revealed that palatability was associated with farmers' *chiso-obhano* (cold-warm) characteristics of tree fodder. These attributes were not necessarily good or bad qualities but were seasonally dependent. Feeding experiments showed that *obhano* fodder was less preferred by goats whilst cattle and buffalo showed no marked tendency of preference. Likewise, farmers' perceptions of *adilopan* generally agreed with the animal studies as *adilo* fodder resulted in a longer duration of appetite satisfaction in the animals. A strong negative association between *adilopan* and potential degradability (gas production) also supported this finding. The *posilopan* of fodders was generally explainable in terms of animal responses (increased milk and butterfat yield with more *posilo* fodders). *Posilopan* showed better correspondence with *in-vitro* measurement of the protein fractions available to ruminants than with other protein fractions. The research demonstrated that farmers in the eastern mid hills possessed considerable explanatory knowledge in their classification, ranking and evaluation of tree fodders. The biological bases of their knowledge for evaluating tree fodder quality have been to some extent confirmed in terms of effects on animal performance.

Further research is suggested into animal responses to feeds, tannins and their detoxification processes and the improvement of dry season feeding using existing feeds and feeding systems through the integration of indigenous and scientific knowledge of tree fodder.

DEDICATION

In loving memory of my beloved late parents
Mr Bhagiman Limbu (*1979 - 2049 Nepali year or Bikram Sambat*) and Mrs Bishnumaya Limbu (*1983 - 2059 Nepali year or Bikram Sambat*) who provided me with encouragement, inspiration and love!

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Abbreviations and glossary of terms used

ADFN	Acid Detergent Insoluble Nitrogen
Adilo	Fodder that satisfies appetite for longer duration of time
ADIN	Acid Detergent Insoluble Nitrogen estimates cell wall nitrogen
AFS	Actual Fodder Supply
AKT	Agro-forestry knowledge toolkit
AOAC	Association of Official Analytical Chemists
ARS-P	Agricultural Research Station-Pakhribas
Bari	Rain fed upland
Barkhe ghans	Wet season fodder
Bekkame ghans	Poor quality fodder
Bhari	One back-load of weight, normally weighing 35 kg of fodder
CEAPRED	Centre for Environmental and Agricultural Policy Research Extension and Development
Cheruwa ghans	Type of fodder that could cause diarrhoea and weakness
Churpi	Very hard local cheese
CP	Crude protein
DDC	Dairy Development Corporation
DFID	Department for International Development
DLS	Department of Livestock Services
Dudh aune	Milk promoting
Dukhako ghans	Fodder for emergency and dry season
Garmi ghans	Summer season fodder
Gharbari	Land close to household
Ghieu	Clarified butter
Ghieu lagne	Butterfat promoting
Hiunde ghans	Fodder for winter
IAP	Insoluble but available protein (IAP).
Kafalopan	Firewood that burns quickly
Kamadiopan	Opposite to *adilopan* see *adilopan*
Kamposilopan	Opposite to *posilopan* see *posilopan*
Kamtikau mal	Opposite to '*Tikaupan*' see *Tikaupan*.
Khar	Grass used for fodder or thatching roof
Kharopan	Firewood that burns intensely with more energy and durability.
Khet	Irrigated low land
Khole	Boiled local concentrate
Kusauro	Legume residues
Lahumute	Red urine
Malilo mal	Fertile manure
Mana	Local volumetric measure (1 Mana of milk is approximately equivalent to 500 ml)
NAF	Nepal Agroforestry Foundation
Naram-kamaadilo ghans	Soft and highly digestible fodder
naramropan	Opposite to *ramropan* see *ramropan*
NARC	Nepal Agricultural Research Project
NDIN	Neutral Detergent Insoluble Nitrogen

NEP	Net change in gas production
Nikhurkama khuwaune ghans	Fodder for critical dry season
Nyno ghans	Warm fodder
Obhanopan	Dry and warm fodder
Pakhabari	Sloping rain fed land
Pet ukasne	Fodder that fills the gut
Pochopan	Firewood that burns slowly often spitting and producing heavy smoke.
Posilopan	Nutritious fodder
Poss lagne	Fodder that enables building muscles
PVPP	Polyvinyl polypyrrolidone
Ramayera khane	Highly palatable
ramropan	Good quality
Ramro ghans	Good fodder, usually highly palatable and nutritious
RDC	Rural Development Centre
RDP	Rumen degradable protein
Rogi ghans	Unhealthy fodder
Ropani	One twentieth of a hectare
Rukho mal	Poor quality manure. Additional manure us required to support the existing crops
SAGUN	Social Action for Grassroots Organisation
Sardi ghans	Cold and wet fodder
SP	Soluble protein
Sukkha ghans	Very *obhano* fodder such as rice straw
Syaule ghans	Low quality fodder
TAP	Total available protein
Tapkan	Raindrops from a tree leaf
Tato ghans	Hot fodder
TEP	Total extractable polyphenolics
Tikaumal	Manure that can sustain at least subsequent crop after its application to a first crop.
UMN	United Mission to Nepal
VDC	Village development committee
NLSS	Nepal living standards survey
GDP	Gross domestic product
IK	Indigenous knowledge
LSU	Livestock standard units
APP	Agriculture perspective plan
DFMS	Department of Food and Agricultural Marketing Services
TDN	Total digestible nutrient
DOMD	Digestible organic matter in drymatter
DMI	Dry matter intake
FMI	Fresh matter intake

CHAPTER 1

GENERAL INTRODUCTION

Overview

This thesis explores local knowledge about tree fodder in the Nepalese middle hills, its biological interpretation and the implications of this for the improvement of farming systems in the region.

This first chapter briefly outlines the farming systems in the hills of Nepal, focusing on the importance of livestock and tree fodder. Constraints on animal production and current efforts of government and non-governmental development agencies to improve fodder resource management and animal productivity are discussed in the light of the available literature. The particular importance of incorporating local knowledge in research and development initiatives to improve productivity of animals in the subsistence farming system in Nepal is also discussed and the aims of the present study and the structure of the remainder of the thesis are set out.

1.1 Farming systems in the hills of Nepal: importance of animals and trees in the system

Nepal is a nation of smallholder farmers. It is estimated that the livelihoods of 95% of households in Nepal depend significantly on agriculture and about 46% of households own less than 0.5 ha (NLSS, 1996). The agricultural system in the middle hills is a combination of crop and livestock production, in which heavy dependence on trees and forest is a significant feature (Thapa *et al.* 1990). Livestock play an important role in sustaining rural livelihoods. The livestock sector contributes about 20% of the total gross domestic product (GDP) and over a third of the agricultural GDP (Anon, 2000). According to Shrestha (1983), the contribution of livestock to the total agricultural income of an average rural household is between 24 and 45%. Besides providing draught power for land preparation, they play a crucial role in facilitating nutrient transfers from common grazing and forest land to privately owned crop land (Robinson, 1990; Thorne and Tanner, 2002).

With the development of infrastructure for milk marketing, there are now many farmers in areas with road access who have been adopting milk production and milk by-products as a secondary occupation for their livelihood (Singh *et al.*, 2000). Agroforestry is a historical agricultural practice in Nepal. Farmers maintain various tree species for fodder on their farm land for a range of economic and cultural reasons. Because of diversity in topography and micro-climate, the availability of tree fodders also varies from place to place in the country. Dhakal (2000) and Subba (2000) in separate studies recorded more than 265 different tree species across all land types from low (<1100 masl) to high altitude (>1700 masl). However, the actual availability of tree species cultivated by farmers on farm land varied from 17 (Rana and Amatya, 2000) to 24 (Dhakal, 2000). Thapa (1994) reported 90 species cultivated on-farm and used for fodder in Solma[5] VDC (Terhathum district); Rusten and Gold (1991) identified 56 tree species as being cultivated on private farmland and used for fodder in the western mid hills. Similarly, Upton (1990) reported some 70 species of trees and shrubs being used for fodder by a hill farming community in the central mid-hills. From a countrywide survey, Kayastha *et al.* (1998) recorded 75 different fodder tree species. Reports on the contribution of tree fodders also varies amongst authors. Pandey (1982) reported that the contribution of tree fodders to livestock diets in Nepal (for the whole country) was from a minimum of 7.5% to a maximum of 90% in the hills.. Rusten (1989) reported that the contribution was from 13 to 90% in the mid hills of Nepal. Fonzen and Oberholzer (1984) reported between 50 and 60% contribution in well-managed farm households in the western mid hills of Nepal. These variations in the estimates could be caused by differences in the amounts of alternative fodder resources available to farmers (Robinson and Thompson, 1989) but there is no doubt that tree fodder is an important resource for livestock production, particularly in the dry winter season when herbaceous fodders are less abundant.

1.2 LIVESTOCK POPULATION, HEALTH AND PRODUCTIVITY OF RUMINANT ANIMALS

Every household in the rural sector maintains animals because of their importance in agriculture and their social and cultural values. The majority of households keep cattle (*Bos indicus*) (73%) and about 52% of households keep buffalo (*Bubulus bubalis*) and/or small ruminants that may be goats, sheep or both (Anon, 1996). Because livestock play a crucial role in the farming

[5] Solma is a village development committee (VDC), located in Terhathum district in Koshi zone in the eastern hills of Nepal where Thapa (1994) conducted his field research. VDC is the smallest administrative and political unit. Each VDC is further divided into nine wards

system, animals with low productivity (in terms of milk yield) are still kept for organic manure production from dung and dung/compost mixtures (Thorne and Tanner, 2002; Robinson and Thompson, 1989).

The total number of large ruminants (cattle and buffalo) and small ruminants (sheep and goats) in the country as a whole are 10.5 and 7.2 million respectively (Anon, 2000a). Of the large ruminants, 12% and 26% of cattle and buffalo are at the milking stage with an average milk yield of 0.40 and 0.83 Mt milk per day for cows and buffalo respectively. Of the total annual meat production, about 64% is derived from buffalo and 21 % from goats and sheep (Anon, 2000a). Cattle are not used for meat for religious reasons within Nepal and it is illegal to slaughter them, but some cattle are sold to traders who sell them for meat consumption across the border in India and Bangladesh.

The average herd size of cattle, buffalo and sheep/goats in the country is 3.3, 2.2 and 4.1 respectively (NLSS, 1996). In the eastern hills, cattle are the most commonly owned animal species. Almost all households in the hills keep cattle or buffalo or both. In the Koshi hills, among the ruminant species 95% of farmers own cattle, followed by goats (85%) and then buffalo (67%) (Gatenby *et al.* 1989). The mean livestock holding per household was four cattle, four goats and two buffalo in the Koshi hills (Gurung *et al.* 1989) but 2.2 cattle and 2.4 buffalo in the Mechi hills (Sharma and Wagle, 1991). Thorne and Tanner (2002) reported that the average livestock holding size in the mid hills is from four to six livestock standard units (LSU).

Ownership of animals varies between ecological zones, the number being higher in hills and mountains compared to the plains, known locally as the *terai* (Anon, 2000b). Rasali *et al.* (1997) reported that in the western mid hills, buffalo are predominant as they are the main source of income and are more intensively managed than cattle. Cattle, however, have the predominant position in farming households in the eastern hills (55% of cows against 45% buffalo) (Gatenby *et al.* 1989). Likewise, the ownership of sheep and goats (mainly goats) is higher in the eastern hills compared to the western hills (65% vs 45%) (Anon, 1996; Anon, 2000a).

Due to an ever-expanding human population, natural forests and grazing lands have been converted into croplands (Oli, 1985). One would expect that the number of animals would increase with increase in land fragmentation due to division of families. Contrary to this, the number of cattle and buffalo are generally declining (Robinson and Thompson, 1989; Rasali *et al.*, 1997; Kshatri, 2000). Goat numbers are, however, increasing in areas where they are able to find enough feed resources (Anon, 2000b). The decreasing livestock population could be attributed to diminishing feed resources and labour shortages (Rasali *et al.* 1997). As a result of this, farming in the mid hills is becoming more intensive, resulting in adoption of stall-feeding systems (Kshatri, 2000). The gradual intensification of livestock production could also be due to the encouragement and stimulation to all categories of farmers from the development of road infrastructure and milk collection networks in the eastern hills (Gatenby *et al.* 1989). As a result, farmers in roadside areas are tending to adopt exotic breeds in preference to local cows. This change away from an extensive and towards an intensive system means that high standards of day-to-day management are needed and each farmer now needs to evolve feeding and management systems to get the best economic returns from the limited available inputs. However, for increased productivity, one would expect the exotic crossbred animals to eat 50% or more feed than local breeds (Singh, 2001) and be more susceptible to endemic diseases and parasitic infestations (Anon, 1990).

The target of the Nepal government's national agriculture perspective plan (APP) to increase overall agricultural production relies on production being achieved from the livestock sector. However, many livestock suffer from malnutrition resulting in poor performance and increased susceptibility to diseases and parasites as a result of inadequate nutrient intake (Panday, 1989; Karki, 1984). Inadequacy of nutrients is perhaps due to decreasing feed availability because of increased livestock populations in the hills of Nepal. The inadequacy of nutrients could also be because the feeds and fodders available in the country are seasonal in nature, so that animals are well fed during the monsoon season and underfed during the dry season (Anon, 1990).

With rising human population, the demand for livestock products is also increasing whilst productivity per livestock unit is decreasing (Robinson and Thompson, 1989). The productivity of animals in Nepal in general is low compared to western standards (Gatenby *et al.* 1989; Robinson and Thompson, 1989). However, the productivity of animals varies from place to place. In terms of milk yield, the productivity of the cows (mainly crossbreeds of *Bos indicus* and *Bos taurus*) in Ilam district is higher than cows (mainly *Bos indicus*) in other hill districts in the country (Anon, 2000; Singh, 2000). However, various authors (Panday, 1989; Kshatri, 2000) have reported that the animals are generally underfed as they receive only about 50 to 67% of the total maintenance and production requirements. The situation would be expected to be even worse during the dry season when fodder resources are scarce. Shrestha (1983) reported that the average performance of local animals is constrained by their genetic potential, poor nutrition and health problems. According to Oli (1985), the milk yield of local cows is between 1.5 to 3.2 litres per day, a difference of about 113%. This clearly suggests that there is scope for improvement of native breeds and through appropriate feeding, so as to achieve the maximum genetic production potential. Gatenby *et al.* (1989) made similar assumptions in their report.

The major reasons for low livestock productivity are, therefore, the low genetic potential of the native breeds and a lack of sufficient feeds or fodders (Panday, 1997). It has been estimated that there is approximately a 36% fodder deficit with the existing livestock population in Nepal (Pande, 1994). Perhaps because of poor nutrition, most farm animals in the hills of Nepal suffer seasonal weight loss and are susceptible to infection from parasitic diseases (Thakuri *et al.* 1992). The poor nutrition of animals is further reflected in the long calving interval (approx. 16 months), delayed age at first calving, ranging from 48 to 56 months (Oli, 1985; Panday, 1997; Anon, 1990) and relatively short lactation lengths (245 days for cattle and 294 for buffalo) (Oli, 1985).

Although moderate to low levels of animal performance may be biologically inefficient, they may be more economically viable than high levels of performance especially within the limitations of small farm systems (Singh, 2001). Because of this it is essential that on-farm work with the participation of farmers should be undertaken in the context of farming systems research to develop improvements that are compatible with resource availability.

1.3 Constraints in animal production

In Nepal the dry season, that begins from October/November and runs to April/May, is the season when animals receive inadequate supply of feeds and often suffer from under nutrition, subsequently becoming susceptible to diseases (Panday, 1989) and low in productivity (Robinson and Thompson, 1989). Almost all types of farms face the problem of feed shortage during the dry season. Rai and Thapa (1993) reported that in places like Mustang (a high altitude mountainous area), an average of 10 to 15% of the animals die each year during the dry season, particularly in the months of March and April.

Livestock density per hectare of cultivated land in the hills is high, around 6 to 7 LSU ha^{-1} (Heuch, 1986; Oli, 1985). Disruption of the seasonal movement of Nepalese herders to winter pasture in the Tibetan plateau (Rai and Thapa, 1993), has added further pressure on grazing lands and there has been a history of uncontrolled lopping of forest trees for fodder in the mid hills that has led to forest degradation and widespread introduction of community forest management schemes that restrict access (Pokharel, 2000).

Most farmers have various strategies to adjust to fluctuations in the seasonal feed supply. Some farmers sell out their livestock during crisis periods or keep them with neighbours or relatives. Grazing at roadsides, scavenging, and collection of forest fodder are the most common strategies for mitigating feed shortage of livestock in the hills.

On the other hand, due to work pressure, some farmers allow animals insufficient time for grazing and provide inadequate amounts of fodder. As a result, the animals need to satisfy their appetite from the limited food they are provided in the stall, which are generally low quality roughages. Although lactating and growing animals are better cared for and given better feed (Gatenby *et al.* 1989), low nutritive quality and underfeeding could be a serious problem in oxen and dry cows, which are often neglected. However, the extent to which a lack of nutrients is responsible for low production rates in Nepalese animals is as yet unquantified.

1.3.1 Efforts to improve animal productivity and management of fodder resources

Although improved species of forages are widely advocated for promotion (Neopane and Shrestha, 1991; Shrestha and Mahato, 1992), this has not always met with success in the villages in the eastern hills (Katuwal *et al.* 1998 and Dhungana *et al.* 1998). Shrestha (1992) suggested integrating oats and berseem in rice-fallow systems as a practical approach to increasing availability of fodder and improving the feeding value of crop residues. However, any grass, which remains green at this time of the year, tends to be grazed by wild animals and most plants, including fodder tree seedlings, do not survive grazing.

Various authors in Nepal (Shrestha and Dhaubadel, 1987; Bajracharya, 1985; Dhaubadel, (1992); Chemjong *et al.* (1990); Chemjong, 1989, Oli and Shrestha, 1986) have suggested that treatment of rice straw with urea may be economically viable and successful in improving the productivity of farm animals. The possibility of treatment of wheat straw and maize stover with urine (Khanal, 1997) and silage from maize stover has also been explored (Poudal, *et al.* 1994). These technologies have been experimented on extensively and promoted generally in South-East Asian countries (Jayasuriya, 1985), but they have not been adopted widely by target communities in Nepal. An impact study conducted with 134 farmers in four districts in the Koshi hills (Shrestha, 1992) revealed that only 1% of farmers or less were practicing urea treated rice straw, and none were encountered when this author visited the same sites in 2002. The reasons for lack of adoption included a lack of awareness of the technology, a shortage of labour and a lack of availability of basic inputs such as urea and plastic sheets necessary for the treatment of rice straw.

Subba (2002) demonstrated the possibility of conserving fodder for use in the dry season in the form of hay or silage. Singh (2000) emphasized the need for conservation of flush season forages as hay for deficit season feeding in the high hills. Gatenby *et al.* (1989) have also reported the possibility of conserving forage grasses or crops as hay or silage. However, they also pointed out that rain interrupts the drying process in the field causing spoilage of hay. Also, the seasonal abundance of forages coincides with the main cropping period, so that labour is not generally available for hay or silage making. In addition, farmers are unwilling or unable to buy basic inputs to make good quality silage (Gatenby *et al.* 1989; Singh, 2000).

Conserving leaf fodder from woody species has also been explored. Feeding of dried leaves of *Zizyphus spp*. is a common practice in Pakistan to improve the nutritive value of crop residues (Ahmed and Butt, 1994). Savory *et al.* (1980) explored possibilities of drying leaves of *Leucaena* and their storage in bags for winter-feeding. Balaraman (1996) in North India explored the feasibility of making hay from the leaves of Nebharo (*Ficus auriculata*) and concluded that the hay (dry leaves) could be used as sole roughage for the maintenance of adult goats. However, this was only viable in situations where there was a great abundance of tree leaves.

1.4 Role of tree fodder in hill farming systems

More than a third of Nepal is covered by natural forest, but most of this is confined to the less accessible slopes of hills and mountains (Anon, 1986). Trees provide raw materials in the form of forage and fodder for animal feed, leaf litter for both animal bedding and composting with dung to provide manure, and fuel and timber resources for heating, cooking and construction. In order to sustain the mixed hill farming system, farmers in Nepal maintain a variety of multipurpose trees on farmland. The usefulness of tree fodders as a feed resource particularly during the dry season has long been recognised by Nepalese farmers (Thapa *et al.* 1990) and throughout the tropics (Larbi *et al.* 1996). They are well known to farmers and are better adapted to the local environment than exotic plant species. They play a crucial role in sustaining livestock production, productivity and sustenance of farming systems.

Shortage of nutritious green fodder is one of the most important constraints to increasing animal production in the hills of Nepal. Fodder trees, however, make useful contributions towards mitigation of this problem by providing a source of protein, energy and mineral elements (Khanal and Subba, 2001; Subba, 1999). They often contribute to year-round green fodder supply by making up a significant proportion of the daily diet of animals (Pande, 1994; Subba *et al.* 1992; Gatenby, 1989). A small proportion of tree fodder can enhance the voluntary intake and digestibility of low quality roughages (Devendra, 1989). They can be harvested from November to June, depending upon the availability of other feed resources, particularly green forages, and the number of fodder trees a farmer owns (Thapa, 1994). This provides the farmers with a wide range of choice in the cultivation, management and harvesting of tree fodders depending on their availability and accessibility to a farm household.

Farmers in the hills offer little or no nutrient supplements, except occasional feeding of common salt and a small amount (typically 100g) of cereal by-products sometimes given to lactating animals, while commercial compound feeds are costly and generally unaffordable. Hence, in the dry season, farmers largely rely on tree fodders to meet the nutrient requirements of animals. Because of their importance, trees are retained on crop terrace risers even though they may have negative impacts on crop productivity (Thapa *et al.* 1995).

The gradual intensification of livestock production systems has made farmers increasingly dependent on the cut and carry system, which relies particularly on the use of tree fodders (Gatenby, 1989). According to Gatenby *et al.* (1989), even at the end of the dry season about 60% of the fodder provided to buffalo is green, which is achieved by feeding tree fodder. However, Fox (1983), cited by Robinson and Thompson (1989), estimated that the contribution of tree fodder was from 25 to 28% of the total dry matter supplied to large ruminants. The contribution was similar in Bhutan where the landscape is similar to that of the middle hills of Nepal (Roder, 1992).

1.4.1 Nutritive value of tree fodders

In terms of the use of tree fodders, large ruminants such as cattle and buffalo are the most important ruminant species (Sharma, 1985). Tree fodder is a valuable source of nutrition that makes an important supplement to the ruminant diets during the dry season (Devendra, 1989; Rangnekar, 1991; Subba, 1999; Subba, 1998) in the hills of

Nepal. In the smallholder farming system in the hills, tree fodder is often the main or even the sole source of protein supplements to low quality crop residues.

Forests, grazing lands, crop by-products, and vegetation growing on terrace risers and bunds are the major sources of animal feeds in Nepal. In the mid hills, of the total available TDN (total digestible nutrient)[6] it has been estimate that nearly a third is derived from cultivable land while over half comes from forest land and the rest from pasture or shrub land (Rajbhandari and Pradhan, 1991). It has been estimated that a total of 9.46 Mt of TDN is required annually to feed the total livestock population in Nepal; of which about 5 Mt is needed for cattle, 4 Mt for buffalo and the rest for sheep and goats (Pande, 1994).

Several tree species grown on terrace bunds and wastelands are commonly used to feed animals in confinement (Gilmour, 1997; Thapa, 1994). The value of feeds as supplements depends mainly on their capacity to provide nutrients that are deficient in the basal diet (Devendra, 1989) and essential for increasing the efficiency of feed utilisation (McDonald *et al.* 1995). In general, most of the indigenous fodder tree species are adequate for most nutrients (Khanal and Subba, 2001; Subba, 1998; Subba, 1999). From 264 fodder tree species, Subba (1999) obtained more than 82% of species with more than 11% crude protein (CP) and more than 54% of species with more than 14% CP. Of the 264 different species of trees, Subba (1999) obtained more than 77% of tree fodders with DOMD (digestible organic matter in dry matter) content more than 50% and about 30% of species with more than 10 MJ kg^{-1} DM of estimated metabolisable energy content. He also found that a majority of tree fodders (>51%) contained high levels of the major mineral elements particularly Ca, Mg and K whilst 65% were deficient in Na content. However, since occasional supplementation of common salt is a traditional practice, problems associated with sodium deficiency are unlikely.

The most common natural toxicants occurring in tree fodders are tannins, although mimosine is a major toxicant present in Ipil-ipil (*Leucaena leucocephala*) and caumarin in Gliricidia (*Gliricidia sepium*) (Devendra, 1988; Makkar, *et al.* 1986). Tannins are widely distributed in tree fodders, which adversely affect the digestibility of dry matter and important nutrients (Makkar *et al.* 1986). Raghavan (1989) reported that fodders free of condensed tannin increased digestibility of food whilst levels of condensed tannin between 3 to 5% limited the digestibility

[6] Total digestible nutrient (TDN) is a measure of nutrient supply from food is calculated considering proximate principles.

of food. However, tannin has also been found to be effective in protecting dietary protein from proteolysis in the rumen, making it available in the lower gut for absorption (Muellar-Harvey and McAllan 1992).

Tree leaves containing high levels of tannins generally have low palatability. As ruminants have restricted selectivity during the dry season, they are forced to eat tannin rich fodders (Subba and Tamang, 1990). Of 250 different tree species analysed, Subba (2001) found that more than 80 % of tree species had tannin levels (tannic acid equivalent) below 5%. According to Ologhobo (1989) minimum tannin concentrations adversely affecting digestibility are between 2 and 5% in sheep and cattle and up to 9% in goats. Wood *et al.* (1994), in measuring 13 species of Nepalese fodder trees, found that tannin concentration fluctuated widely with season. Metabolic disturbances and livestock deaths as a consequence of this are rare under natural conditions in Nepal, although Makkar *et al.* 1986 reported that continuous feeding of fodders high in tannin can cause poisoning and death.

Besides tannins, another phenolic compound regarded as contributing to low quality of tree fodder is lignin, which is found in association with mature tree leaves (Subba *et al.* 1996). Subba (2001) found that 76% (of the 264 different tree species analysed) had lignin levels of more than 10% in dry matter. Lignin reduces animal performance by limiting food intake and availability of nutrients, mainly carbohydrate (Van Soest, 1983). Also, an increase in the degree of lignification subsequently decreases protein mineral availability in ruminants (McDowell and Conrad, 1990).

Knowledge of the deleterious effects of some plants, including fodder trees, and subsequent antidotes for the conditions that they cause is familiar among farm communities (Aryal and Singh, 1999; Subba and Tamang, 1993). Panday (1982) listed some common fodder tree species recognized locally as having negative effects on ruminants, such as *Bauhinia variegata, Ficus auriculata,* and *Prunus cerasoides.* Scientific reasons for these effects are uncertain (Joshi and Singh, 1989). Farmers currently overcome and reduce deleterious effects by feeding after leaving the lopped fodder overnight to wilt or by feeding mixtures of different species (Devendra 1989). The practice of feeding a mixture of different fodders not only extends the choice of feeds available but also dilutes the toxicity and reduces problems of palatability and other deleterious effects. Little is known about optimum dietary levels of feeds from locally available feed resources, how to reduce the incidence of deleterious effects, or design of suitable feed mixtures for economic diets for ruminants.

1.5 Local knowledge systems

Uptake of much past research directed at alleviating the adverse effects of seasonal feed shortages and improving animal performance has been disappointing in Nepal. Farmers must, however, continue to cope with lean periods in fodder supply that may last for several months. One of the main reasons for low uptake of research outputs could be because the research was planned without sufficient understanding of the needs of local communities. Only recently have researchers and development agencies understood the necessity of including the local community in the technology development process.

Recognition of farmers' knowledge has been steadily gaining momentum in sustainable development (Warren, 1991) and there is growing awareness among development professionals of the value of enhancing scientific and professional understanding with the detailed knowledge held by farmers (Rangnekar, 1991; Warren, 1991). Walker *et al.* (1995), proposed tools for accessing, recording, evaluating and synthesizing local knowledge on specified topics. Local knowledge is not only the knowledge and beliefs transmitted from generation to generation, obtained as a result of experience (McClure, 1989; Niamir, 1990) but also a dynamic resource modified by contemporary experience and experimentation (Sinclair and Joshi, 2000). Explicit records of local knowledge can serve a useful function in helping to understand target farm communities, and identifying and prioritising research objectives leading to more appropriate, well-focussed and effective research (Walker *et al.* 1995).

Local knowledge can be distinguished from conventional scientific understanding in that it represents what people in a defined community know. While some of this may be acquired from external sources, a lot may be locally derived understanding, based on local experience and observation and may incorporate cultural beliefs and values (Joshi and Sinclair 2000). The acquisition of knowledge in the present study was carried out using knowledge-based systems methods developed and tested in several countries including Nepal (Sinclair and Walker, 1998; Walker and Sinclair, 1998). Using this approach, knowledge bases are created by eliciting knowledge by talking to farmers, and then translating their answers into sets of statements on computer using a restricted syntax and defining the formal terms used and their taxonomic relationships. Once established, knowledge bases can be used to compare and contrast local and scientific knowledge systems (Warren, 1991), which, where complementarity exists, may be a powerful and efficient means of filling gaps in both scientific understanding and local knowledge. Today, following a largely anthropological tradition, the linking of indigenous and scientific knowledge is in need of novel and more comprehensive approaches that acknowledge the diversity, dynamism and multiple dimensions of local knowledge, and the broad range of its contributions to sustainable development (Walker *et al.* 1995). Of particular significance for technology adoption are integrated approaches that combine local and scientific knowledge, to consider problems and objectives of local communities in scientific terms.

The rapid pace of environmental change and population increases may exceed the capacity of farmers to adapt their indigenous knowledge systems. The integration of these with biological information should assist in responding to such changes and making responses adaptable to local settings (Warren, 1991).

1.5.1 Use of tree fodders in Nepal

Resource poor farmers in Nepal have a knowledge system for describing the nutritive value of fodders from a wide range of tree species that are used as dietary supplements for ruminant livestock (Rusten and Gold, 1991; Subba, 1999; Thapa *et al.* 1997). The extreme diversity of on-farm tree fodder resources reflects a sophisticated understanding of the comparative value of tree fodder resources (Thapa *et al.* 1995, Joshi, 1997) held by farmers in Nepal. Based on understanding of tree fodder characteristics, farmers extract fodders from different sources at different times of year for feeding to different categories of animals (Gatenby *et al.* 1989). Thapa (1995) revealed two local classification systems that farmers used to evaluate tree fodders, *posilopan*[7] (nutritive value) and *obhanopan*[8] (literally referring to dryness and

[7] *Posilopan* is a local term for nutritive value, *posilo* fodder is considered to have high nutritive value (improves health and productivity) while *kam-posilo* fodder has less nutritive value.
[8] *Obhano* fodder is considered as 'warm and dry' while *chiso* fodder is considered 'cold and wet'. Farmers differentiate by touching and feeling the leaves between fingers. *Obhano* fodders are considered

warmness but associated with palatability, appetite satisfaction and dung consistency), which are fairly representative across the mid hills (Joshi, 1997). Farmers presently trade-off productivity of crops and livestock in making feeding decisions. Trees are maintained in close proximity to crops although they are known to cause negative effects on crop yield (Thapa *et al.* 1995) and cattle are fed low digestibility feeds in order to control animal behaviour, indicating that there is a key constraint in the system that can be addressed by improved feed planning (Thorne *et al.*, 1999).

Laboratory data are available for a wide range of Nepalese local feeds (Subba, 1998; Panday 1982; Panday, 1997; Khanal and Subba, 2001), which can be used to estimate their feeding value. However, laboratory analysis may not be sufficient to completely evaluate feeds in a local context since farmers use various types of feed in animal diets and different farmers may have different objectives in managing their animals. In addition, tree fodders may contain anti-nutritive factors which influence their palatability and feed utilisation but are not taken into account in laboratory analysis. This suggests that laboratory techniques for evaluating fodder might be of little practical value unless interpreted in the light of farmers' objectives. A recent study revealed a contradiction between farmers' ranking of tree fodder and a group of applied nutritionists' ranking of the same group of fodders based on their chemical composition (Thorne, *et al.* 1999). The differences were attributable to farmers considering multiple objectives when incorporating tree fodder in livestock diets.

Studies to date have relied upon comparison of *in vitro* measurements of the nutritive value of fodders with farmers' knowledge. Although the need for animal nutrition research closely linked with farmers' interests is well understood amongst researchers (Panday, 1989), information on quantitative comparison of farmers' knowledge with effects on animal performance is limited in Nepal. Some information about the value of tree fodders is available from on-farm feeding trials (Shrestha and Pakhrin, 1989; Poudel and Rasali 1996; Rana *et al.* 2000) but none of these studies have interpreted the biological basis of the local descriptors of fodder value.

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highly palatable, to promote solid dung and to satisfy appetite for a long time, the opposite is true for *chiso* fodder.

Recently, Thorne *et al.* (1999) compared farmers' ranking of fodders with chemical analyses and found that *posilopan* appeared to correspond to protein supply to the duodenum in cattle, while *obhanopan* appeared to correspond to *in-vitro* digestibility. More recently Thorne *et al.* (2000) have illustrated the utility of a simple model to combine the qualitative knowledge of farmers about a wide range of tree species with quantitative scientific data. They have demonstrated how models combining farmers' knowledge with biological interpretation can provide rational explanations for farmers' feeding decisions.

1.6 PURPOSE OF THE STUDY

This study builds on previous research on local knowledge on the use and management of farmland tree fodders in Nepal (Thapa *et al.* 1997; Joshi, 1997; Thorne *et al.* 1999; Walker *et al.,* 1999).

The study aimed at understanding the current use of farmland fodder resources, the supply of nutrients to livestock and their impact on the productivity of animals. More specifically, the study aimed at assessing the nutritional status of large ruminants particularly in terms of dry matter, protein and energy availability and to use the insights obtained to suggest appropriate interventions for improving and supporting their nutrition.

Building on previous knowledge acquisition, the present study aimed to provide a picture as to how farmers manage animals and local feed resources to mitigate dry season fodder shortages. It also aimed to critically examine the fodder evaluation methods practised by farmers and to use these results in combination with scientifically conducted feeding trials to explain farmer knowledge and decision making strategies.

Specifically the study aimed to examine the correspondence between local and scientific evaluation of tree fodders, by exploring how local descriptors of fodder quality relate to animal performance in both on-farm and on-station conditions. The results are used to suggest ways to improve intake, palatability and voluntary intake of tree fodders during the fodder scarcity period of the dry season, by integrating local and scientific knowledge about tree fodder.

1.7 STRUCTURE OF THESIS

The thesis is presented in a series of chapters beginning with assessment of farmer practice and knowledge through specific feeding trials exploring impacts of tree fodders on animal productivity and then their palatability, intake and tannin content. Effective utilisation of existing fodder resources and promotion of potential species of tree fodders, for improved animal productivity, were recommended for use by local people and for future research.

Chapter 2: The role of tree fodder in feeding large ruminant livestock in the eastern hills

This chapter presents background information about the study sites. On the basis of surveys, information is derived on the number of ruminant animals kept, the fodder resources available throughout the year and the productivity of lactating cattle and buffalo. Based on repeated measurements carried out for one year, intake of nutrients in the form of dry matter, protein and energy for different categories of animals were calculated. Opportunities for improving nutrition of farm animals within the existing feeds and feeding systems are discussed.

Chapter 3: Local knowledge on utilisation and management of tree fodders during the dry season

This chapter outlines the importance of local knowledge in agricultural research. Creation of a knowledge base on the use and management of tree fodders, local strategies to cope with dry season fodder shortages, and the use of attributes to describe fodder quality are presented. In addition to the local *posilopan* and *obhanopan* descriptors of fodder quality previously identified, farmers were found to use a more specific descriptor, *adilopan*, relating to the duration of appetite satisfaction that is further explored in feeding trials in Chapter 6. The local knowledge about the *posilopan* and *obhanopan* descriptors formed the basis for feeding trials on animal productivity (Chapter 4) and palatability (Chapter 5), respectively.

Chapter 4: Impact of feeding different tree fodder on productivity of lactating cows

This chapter explores farmers' *posilopan* descriptor of tree fodder value (derived from Chapter 3) by quantitatively measuring visible outputs of performance (milk and butterfat yield) in 78 lactating local cows under on-farm conditions, when fed one of 14 of the most common species of tree fodder as a supplement to a basal diet, each fodder replicated in from two to 11 animals depending on their availability, with ten fodders replicated in four or more animals and six fodders replicated in six or more animals.

Chapter 5: Investigating farmers descriptors of the palatability of tree fodders

Chapter 5 compares farmers' use of the *chiso-obhanopan* descriptor of tree fodders (derived from Chapter 3) by means of a cafeteria trial under both on-farm and on-station conditions in cattle, buffalo and goats to understand and ascertain the relationship between farmers' ranking and animal preferences of the same species of tree fodder. How the feeding time and length of experimental period influences intake and selectivity in animals are discussed.

Chapter 6: Investigating farmers descriptors related to voluntary intake of tree fodders

Chapter 6 examines farmers' knowledge about *adilopan* (derived from Chapter 3) in relation to behaviour of animals under restricted feeding conditions conducted both under on-farm and on-station conditions in cattle, buffalo and goats for six different species of trees varying in their *adilopan* characteristics.

Chapter 7: Quantifying relationships between *farmers' descriptors of fodder value* and tannins, proteins and gas production

Chapter 7 further explores associations between farmers' *posilopan* descriptor and protein (and its fractionates) as modified by anti-nutritive factors (tannins). Their *adilopan* descriptor is examined in light of the gas production characteristics of tree fodders.

Chapter 8: Overall conclusion

This concluding chapter brings together the research findings and discusses their implications for the improvement of the nutrition of farm animals, particularly during the dry season, in the middle hills of Nepal.

CHAPTER 2

THE ROLE OF TREE FODDER IN FEEDING LARGE RUMINANT LIVESTOCK IN THE EASTERN HILLS

Overview

This chapter reports on an investigation of the role of tree fodders in the hill farming system in the middle hills of Nepal. General background information on the study sites is followed by information on fodder resources and their seasonality, animal numbers and productivity of lactating animals at the study sites derived from questionnaire surveys. Intake of nutrients in the form of dry matter, protein and energy for different categories of animals were estimated from repeated measurements carried out for one year in five different sites in the eastern mid hills of Nepal. In light of the fodder situation and nutrient availability obtained from the current feeding systems, this chapter discusses opportunities for improving nutrition of farm animals within the existing feed and fodder resources. This information forms a basis for understanding farmers' problems associated with feeding and management of large ruminant livestock throughout the entire calendar year.

2.1 Introduction

Livestock have traditionally been integral components of the farming systems in the hills of Nepal and have an important bearing on the farming economy in the country. The overall population of cattle in the country is declining (Anon, 2000) whilst the number of buffalo is increasing. A decreasing cattle population may indicate that larger individual animals of improved breeds and crosses are rapidly replacing the smaller local animals as well as reflecting depletion of fodder resources available from communal forest and grazing areas reducing the overall livestock carrying capacity of farm systems.

In Nepal many trees are traditionally planted and maintained predominantly for fodder production. The role of tree fodders is important to the annual feed supply of ruminant animals in the hills of Nepal, especially during the dry winter season. It has been estimated that more than 35% of animal feed dry matter (DM) is derived from trees in the hills of Nepal (Panday, 1982; Gatenby *et al.,* 1989a). Other localised studies concur. The contribution of privately owned tree fodders to the annual feed supply in the central mid hills was estimated by Rusten (1989) as 33% of DM, while Fonzen and Oberholzer (1984) estimated that the contribution of tree fodders in two villages in the western hills of Nepal was in the range of 50 to 60% DM. Due to rapid increases in human population, grazing lands are being converted into cropland resulting in more acute shortages of animal fodder (Sharma and Pradhan, 1985). With the introduction of new communal forest management plans (Kiff *et al.,* 2000), local people have increasingly limited access to communal forest areas. Restriction of the free access to communal forests and limitation of grazing access have led mid hill farmers to intensify the cultivation and management of fodder trees on their private land.

Farmers have become increasingly dependent on the cut and carry system of feeding management, relying particularly on the use of tree fodders. This increase in dependency on tree fodder is evidenced by an increase in the number of tree fodders in the farmland during the last few years in some villages of the western mid hills of Nepal (Gilmour, 1997).

Various species of tree fodder have traditionally been grown in Nepal. Species and types of tree species grown in various parts of the country differ with climate and altitude (Khanal and Subba, 2001). A survey conducted in 51 hill districts in the country indicated the presence of 266 different tree species used for fodder, of which 24 were considered to be extensively used (Dhakal, 2000). Subba (2000) recorded a similar number (250) of fodder tree species in the eastern hills of Nepal only. These figures are almost three times higher than the number reported by Panday (1985) for all of Nepal. The number of extensively used tree fodder species has been estimated at between 17 in the western hills (Rana and Amatya, 2000) to 34 in the eastern mid-hills (Subba, 2000).

Shortage of green fodder is a main constraint to animal production during the dry season in the hills of Nepal (Dutt, 1993; Panday *et al.,* 1991) when production of green biomass is curtailed by low temperature and low moisture (Thapa, 1985). The availability of animal feed is high during the wet season whilst the feed requirement remains constant throughout the year. Fodder trees are one of the few, relatively reliable sources of green fodder for the dry season due to their ability to retain fresh biomass under cold and dry conditions.

Farmers possess extensive knowledge of the use of fodder trees, from understanding of tree phenology to species-specific effects on animal productivity (Thapa, 1994). Tree species are maintained selectively in the homestead according to their value for specific purposes and their importance at different months of the dry season (Upton, 1990). Species which have multiple uses are generally selected and planted around homestead *bari* land (unirrigated upland areas) (Shrestha, 2000) for convenient collection and management (Carter and Gilmour, 1989; Thapa, 1994). Land unsuitable for food crops such as terraces, bunds, gullies and wasteland are also chosen for tree planting so as to avoid competition amongst trees and crops (Thapa, 1994).

Trees are preferred over grasses as a fodder source by farmers because less labour is required to harvest equivalent amounts of biomass, and tree fodder is available further into the dry season (Kiff *et al.*, 2000). Most fodder trees have multiple uses. Besides use as animal fodder, they are also valued for animal bedding, and for household uses such as fuel, timber, fencing and green manure in some cases (Sthapit, 1990; Subedi, 1997). Depending upon their availability, they often contribute a year-round green fodder supply to the diets of ruminant livestock.

Usefulness of tree fodders as a feed resource, particularly during the dry season has long been recognized and Robinson and Thompson (1989) have emphasized the importance of understanding their actual and potential role in improving productivity of farming systems in Nepal. Available data suggest (Subba, 2000) that fodder trees generally contain between 12 and 25% DM of crude protein, a level more than sufficient for maintenance and production requirements if tree fodder was a sole feed (Norton, 1982), but often it is a supplement to a basal diet of cereal straw. Trees have also been reported as being an important source of dry matter, energy and mineral elements, particularly calcium and phosphorus (Khanal and Subba, 2001). The relatively high levels of protein, minerals and energy in tree fodders underline their importance in the nutrition of ruminant animals in the hills of Nepal.

The nutritive value of dry roughages (mainly crop residues and some conserved dry grasses) is often low (Greenhalgh, 1980) and animals may not be able to eat sufficient amounts to meet their requirements for maintenance and work (Zerbini and Wold, 2002). Farmers in Nepal have already valued the use of fodder trees as important feed supplements to improve the utilization of low quality crop residues in the dry season. Animal response trials incorporating 4% tree fodders had a positive impact on milk production in lactating animals (Shrestha and Pakhrin, 1989; Rana *et al.*, 2000), and on draught animals (Pearson, 1990) as well as contributing to control of gastro-intestinal nematodes (Subba *et al.*, 2000). Although tree fodders are known to be rich in natural antinutrients such as tannins, that may have both positive and negative impacts on nutritive value of rations (Makkar, 2001), tree fodder based diets may also be highly economic. A simple financial model constructed by Pearson and Holloway (2000) suggests that tree fodders are the most cost-effective way of raising ruminants in the mid hills of Nepal.

Over the past 10 years, there has been an increasing trend amongst farm households in the mid hills to maintain milk animals entirely in stall-feeding systems (Upadhyaya, 1991; Singh *et al.*, 2000). This was initially found in areas with good access to markets such as Fikkal in Ilam district but has now spread to other less accessible eastern hills areas such as Sindhuwa and Patle in Dhankuta district. Farm households practising such an intensive feeding system clearly need to operate intensive management.

In order to maintain animals in good health and increase their productivity and so also crop productivity from their draught and manure inputs, they should be well-fed. In order to achieve this, there is a need to understand the current use of farmland fodder resources and the consequent supply of nutrients for animal productivity.

Assessment of the nutritional status of large ruminants in terms of dry matter, crude protein or digestible crude protein and metabolisable energy, particularly during the dry season is important. This will identify opportunities for improving the contribution of existing local fodder resources to support the nutrition of farm animals.

The overall objective of the research reported in this chapter was to quantify the fodder resources utilised in eastern mid hill farming systems and the extent to which they satisfy animal demand for nutrients throughout the year. This provided a basis for exploring strategies for improving livestock productivity through using fodder resources to better match nutrient supply and demand. This involved addressing four specific objectives which were to:

1. characterize the feeding practices of farmers in the eastern mid hills and the ways in which these change over the year,
2. identify critical periods of feed shortage by quantifying nutrient availability from what was fed in relation to animal requirements,
3. identify existing local strategies for managing feed supply during these periods, including the utilisation of tree fodder, and
4. identify opportunities for using tree fodders to improve animal nutrition during these periods.

2.2 Materials and methods

2.2.1 Site selection

Five village development committees (VDCs) were selected across the eastern middle hills to be reasonably representative of cattle and buffalo keeping in the region. These VDCs were located in four hill districts, namely Sankhuwasabha (Mamling), Dhankuta (Sindhuwa & Patle), Terhathum (Fakchamara) and Ilam (Fikkal). Livestock keeping in the region is heavily influenced by road and associated market access because this affects both availability of inputs and the price and opportunities to sell products, reflected in more intensive animal management in more accessible locations. Both accessible and remote sites were selected to reflect the range of accessibility in the region. Mamling and Fakchamara had poor road and market access, being more than three hours walk from the nearest motorable road at the time the research was conducted, whilst Sindhuwa, Patle and Fikkal were more accessible. The production goals of the farmers with good accessibility to markets were more towards milk production for sale whilst sites with poor market access were more concerned with subsistence production, primarily manure to fertilise crops, followed by milk and ghee production.

2.2.1.1 Patle

Patle lies on south facing slopes at mid altitude (1300-1600 m), approximately a one hour walk north from the Dhankuta district headquarters (Figure 2.1).

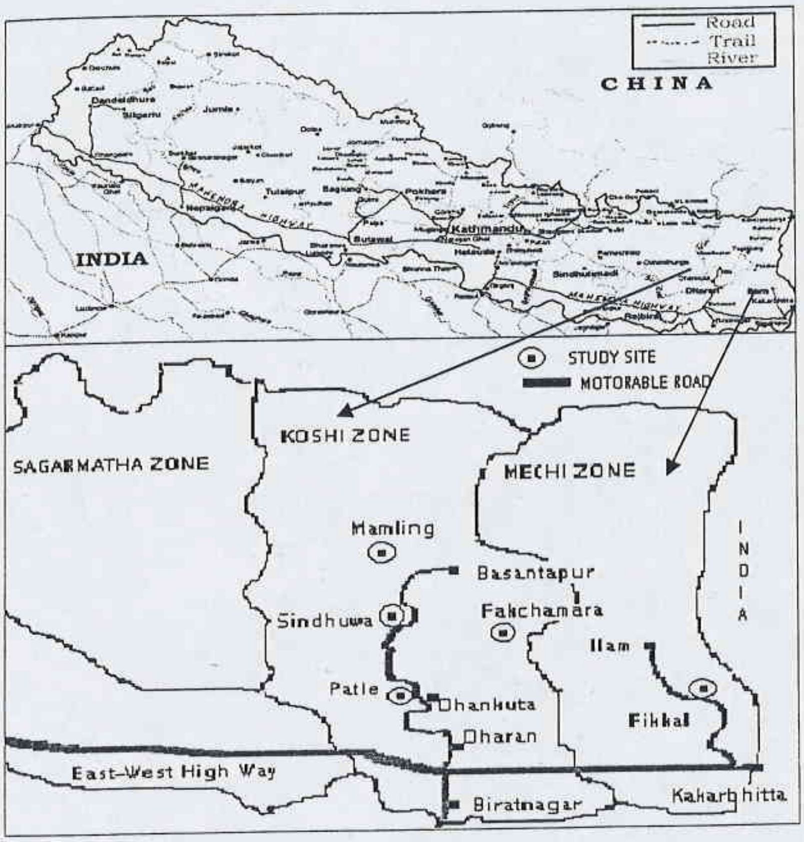

Figure 2.1 Figure showing study sites in the eastern mid hills of Nepal

Patle had good access to roads and well developed marketing opportunities and farmers there had already had a lot of contact with research and development activities. Most farmers were interested in improving the productivity of their dairy cows through cross breeding and replacing their existing animals with more productive cows. Mostly the cattle used for milk production were Jersey crosses with from 50 to 75% exotic blood. A few farmers also owned buffalo. Farmers in Patle had access to milk marketing systems. Milk was collected by a chain of milk collection and chilling centres established by the Dairy Development Corporation (DDC) located in Biratnagar in the eastern Terai. Given the opportunity of marketing their milk, most farmers in Patle (and

Sindhuwa) have been stimulated to maintain milk animals and to produce more milk. Recently the farmers' group also established their own milk-processing unit at Hile, where yoghurt, *ghee* and *churpi* (very hard cheese) are the main products. Animals are most often stall fed with occasional grazing between cropping periods. Intensification has led to increasingly high standards of day-to-day management. Patches of forest cover can be seen on the landscape; however, fodder trees cultivated on farmland were the main source of tree fodder for the stalled animals. During the dry winter, farmers also collect and pay for forest undergrowth from the citrus research program[5] office premises at Paripatle, located about one hour walk from the main study site.

2.2.1.2 Sindhuwa

Sindhuwa was also in Dhankuta district, located north of the district headquarters. The study was concentrated in Sindhuwa hamlet within Parewadin VDC, located between 1500 to 1700 m asl. The Koshi zone highway from Dharan to Terhathum district crosses Sindhuwa. Due to access to this road and the potential it offers for marketing, local farmers were involved in commercial vegetable growing and livestock enterprises, especially milk. Farmers in Sindhuwa were introducing crosses of exotic cows and buffalo. The cows were brought from Fikkal in Ilam and the buffalo from the *Terai.* Milk produced locally was taken to milk collection points operated by the DDC or sold to local shops. Patches of forest were still evident in the landscape. Lactating animals were most often stall-fed but other animals were allowed to occasionally graze fields between cropping periods. During winter, the farmers were mostly dependent on dry roughage, vegetable waste and tree fodder to feed their animals, the dry roughage included crop residues and dry grasses, which are often called *khar*[6].

2.2.1.3 Fikkal

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[5] Citrus Research Program: A research station within the Nepal Agricultural Research Council (NARC), mandated to conduct research on citrus fruits, mainly mandarin. The Station distributes saplings and seedlings of mandarin trees, conducts training and advisory services to the farmers on aspects of cultivation, management, propagation and diseases of citrus fruits.

[6]*khar* is available in the sloping forest/waste land and is used mainly for thatching roofs.

Fikkal is in Ilam district, located about 3 km from the Indian border. The Outreach Research Division at Agricultural Research Station[7], Pakhribas (ARS-P) had identified Fikkal as a site of high production potential with access to roads and markets. It is the only VDC in the Kingdom, which has road accessibility to all of its wards. Fikkal is an area with progressive, motivated farmers who have had considerable exposure to research and development organisations. Types of animals maintained by the farmers appear to have been influenced by market access conditions with crossbred cows preferred over buffalo. The farmers were practising dairy farming integrated with high value crops such as cardamom, ginger, broom grass, tea and potato. According to the Livestock Services Sub-centre, 72% of the total ruminants are cattle and of this 57% are exotic (about 64% of farmers maintain buffalo in areas of Ilam with poorer access). The exotic breeds were mainly Jersey and Holstein, brought across over many years from Darjeeling in India. Increasing demand for milk and milk products and accessibility to markets has bestowed the farmers of Fikkal with an immense opportunity to benefit from dairy production for regular cash income. Almost all farm families in Fikkal regularly sell milk to both the private sector, run by the milk producers' co-operative societies (Poudyal, 2001)`and government agencies such as the DDC. Milk is collected by the chain of milk collection and chilling centres established by DDC and private milk processing industries nearby. Animals in Fikkal are permanently stalled. As the farmers have considerable impetus for increasing milk productivity, they are more oriented towards the use of cereal based compound feeds.

2.2.1.4 Fakchamara

Fakchamara is located at an altitude ranging from 1100 to 2000 masl in Terhathum district. The nearest VDC by road is Sindhuwa, which is about 3.5 hrs walking distance away. Due to its remoteness, there has been very little or no intervention from research and development activities of agencies/institutions. Agricultural Research Station, Pakhribas identified

[7] ARS-Pakhribas (formerly Pakhribas Agricultural Research Centre and funded by ODA) located in Dhankuta district in the eastern mid hills is a research station administered by the Nepal Agricultural Research Council (NARC). ARS-Pakhribas undertakes an intensive programme of research and other inter-disciplinary activities aimed at improving the quality of life in the eastern hill region and with relevance to all hill areas of Nepal. The Station develops, adapts and introduces technologies suitable for the hill environments and helps farmers raise their standard of living through increased, sustainable productivity.

Fakchamara as a low production potential area without access to roads and markets. In contrast to the more accessible VDC's, almost a third of the land cover remains as forest: the amounts of cultivated land, forest land, wasteland and others were 59%, 27%, 7% and 7% respectively and the majority of cultivated land was *bari* (non-irrigated upland terraces). Lack of technical know-how is thought to be a major constraint to livestock production in the VDC (Katuwal *et al.*, 1998). Apart from a few lactating animals, which were stall fed, in general, animals in Fakchamara, were allowed to graze according to the cropping calendar and availability of fodder. The animals were moved to the crop fields just after the harvest of summer and winter crops to utilize dry roughage and leave their manure in the fields. The animals at lower altitude (below 1100 m) are often taken to forest, riverbanks and wastelands for grazing. However, the current study was restricted to areas between 1500 to 1600 m.

2.2.1.5 Mamling

Mamling is in Sankhuwasabha district in the middle hills. It stretches along a south-facing slope with elevations ranging from the Arun river base (about 100 m) to an altitude of over 2000 m. The lower slope is under intense cultivation with high population pressure. The research site at Mamling was about 20 km from Basantpur on the Basantapur, Khandbari foot trail. Like Fakchamara, it had poor access to roads and markets, although there were small weekly and fortnightly markets held at the VDC and since the research was completed a temporary road from Basantapur to Khandbari via Mamling has been constructed. At the time of the research, however, the site had low production potential without direct access to roads and markets. About 80% of the population was engaged in agriculture, 5% service and 1% business whilst about 14% were involved in other activities. Most of the land area was wasteland (53%) whilst cultivated land was only 25%. About 13% of the land was covered by forest. Cattle and buffalo were primarily kept to supply manure to improve the fertility of cropland. Farmers at high altitudes (>1700 m) kept their animals mobile according to season. The animals were housed under temporary shelters in forest lands, where they were supplied with forest fodder. Apart from the milking animals, most animals were kept loose and allowed to graze in the forest undergrowth and on wastelands. Farmers in Mamling VDC only kept local cows but a few farmers had recently introduced crossbred buffalo.

Except for a little scope to sell milk to local hotels and teashops, the farmers did not have opportunities to sell fresh milk on a commercial scale. As a result, farmers with such poor accessibility to roads and marketing preferred to produce ghee ('clarified butter') that has a longer shelf life. Ghee was readily sold in local bazaars that open every week in almost all villages (the price of ghee was approx. 3 \$ kg^{-1}).

2.2.2 Participant selection

The criteria for the selection of households to participate in the study were that they should:

- be located at an altitude between 1400 to 1600 m asl
- own large ruminants
- use tree fodders to feed their animals, and
- show interest and willingness to participate.

Participants were selected by first obtaining a list of potentially suitable farmers who might fit the above criteria, through discussion with the VDC chairman and then meeting at random about 25 of these people while making transect walks across each study site. A final selection of 15 participants in each site was made during the walk, giving a total sample of 75 participants. A team of five people that included the principal researcher, a livestock officer and three field-based outreach staff of ARS-P were involved in the transect walks. Prior to selection, the households were clearly informed about the objectives of the study, the subsequent benefits a farmer may get from it, the visit schedules involved in the research and what their role would be during each visit.

2.2.3 Farm characterisation

Farm characterization was carried out to establish trends in livestock population and their productivity. This was done using a questionnaire survey to:

- record the holding of large ruminants at the study sites,
- estimate their productivity based on farmer's recollection of milk and ghee yields, and

- record the availability of various farm fodder resources (tree fodders, dry roughages, grasses and *khole* (locally produced concentrate feed made from cereal and grain legume by-products, vegetable wastes and other materials available on the farm or homestead).

2.2.3.1 Questionnaire design

The survey consisted of a structured questionnaire five pages in length covering animal feeding and productivity over the whole year (Appendix 2.1). The questionnaire asked for information on livestock numbers and their productivity, feeds used and feeding management of animals and the availability of feeds and fodder resources. Farmers were assisted in calculating the gross milk and ghee yield per lactating cow per year. Data on the numbers and productivity of animals during previous years were gathered by farmer recall.

2.2.3.2 Training of enumerators and pre-testing of questionnaire

Research assistants (two male and two female) from ARS-Pakhribas acted as enumerators for the questionnaire survey. Involvement of female enumerators in the survey was useful particularly to facilitate discussion with the households headed by women. The importance of involving women in the interview process has been stressed by previous workers (Gurung, 2001, Thapa, 1994).

A draft version of the questionnaire was discussed with the enumerators and corrected where necessary. The questionnaire was pre-tested on some households at Phalante VDC and Bhirgaon VDC in Dhankuta. Two enumerators (one male and one female) in each of these VDCs were involved in pre-testing the questionnaire with six farmers. After the test, the enumerators and the researcher discussed problems associated with the use of the questionnaire including the length of time required to complete an interview process. Efforts were made to make the questionnaire as brief as possible so that it could be completed before respondents became bored. Any duplications and ambiguities were corrected.

2.2.3.3 *Data collection and analysis*

The questionnaire was administered by repeated visits to farms throughout the survey period from October 1999 to April 2001, with each farm visited from three to four times. Household heads were interviewed. Generally, at each visit the interview was completed within an hour. Any inconsistencies that appeared during data compilation were clarified by visiting individual households in the same season in the following year. Farmers were only comfortable in recalling numbers and productivity of animals back to 1997. Hence, the information covers three years, from 1997 through 1999.

The data were compiled, tabulated and the variability of milk and butter fat yields was analysed using the General Linear Model (GLM) procedure in the Minitab statistical program (Minitab for Windows 2000, release 13.31). The effects included in the model were year and site.

2.2.4 Longitudinal monitoring

To assess the nutritional status of animals throughout the year, a longitudinal monitoring study was conducted over a full year. This involved repeated visits to each farm to measure the quantities of different fodders actually being fed to animals, together with a nutritive assessment of intake in relation to estimated requirements based upon measurement of animal size and productivity.

2.2.4.1 *Training of enumerators*

Five enumerators (one from each of the VDCs) were appointed as enumerators for one year. The enumerators were farmers with a good reputation in their village and who had the ability to communicate, read and write. The enumerators were briefed about their responsibilities, made aware of the aim of the study and the researcher's principal interests. They participated in training and practical sessions prior to undertaking their responsibilities. Training activities included filling in feed recording sheets, weighing

/sampling and despatch of fodder samples (for laboratory analysis), calculating fodder supply /intake and measuring animals to estimate live weight.

2.2.4.2 Data collection

Each enumerator was supplied with dietary recording sheets (Appendix 2.2) to record the feed intake and a measuring tape to measure animal girth and length to estimate live weight. Body condition of the animals was also recorded (using a scale from 1 to 5) as well as the farmers' assessment of milk yield. The amount of feed supplied and refused by selected animals during a 24 hr observation period was also recorded. Members of participating households assisted in weighing feeds and in the collection of left over fodder. At the time of recording, enumerators discussed aspects of feeding, feed quality and livestock management with participating farmers. Farmers were asked not to graze animals that were being monitored but a few did so and in these cases the intake of animals while grazing was crudely estimated from information recorded on the time that they spent grazing.

2.2.4.3 Visit frequency and animals observed

Recording was carried out twice a month on each participating farm at four of the five sites (Mamling, Patle, Fakchamara and Sindhuwa). In Fikkal there was only sufficient labour for recording once a month. The data recorded at fortnightly intervals was averaged to derive a monthly value so that the reported sampling frequency was regularised across all sites. Seven to eight days (assuming a rate of about two households per day) was allowed for each enumerator to cover their participating farmers during each recording period.

Observations were made twice a day at each visit recording period, once in the morning and once in the afternoon, to coincide with the farmers' normal practice. During the study a total of 48 buffalos, 60 cows, 35 oxen and 48 calves were monitored from September 1999 to September 2001. Recording was made for all buffalo, cows, oxen and calves encountered on participating farms. No buffalo and oxen were monitored in

Fikkal and no oxen were monitored in Sindhuwa because they were not available in sufficient numbers to obtain a large enough sample size.

Table 2.1. Number of animals monitored during the survey at each site (figures are the means and standard deviations for all households at each study site)

Site	Buffalo (cross %)	Cows (cross %)	Oxen	Calves
Patle	15.8±5.0 (59.3)	22±5.5 (46.3)	4.7±1.0	3.00±3.00
Fikkal	0.00	18.6±3.6 (100)	0.00	8.75±2.34
Sindhuwa	11.5±3.9 (1.0)	27.3±6.2 (71.8)	0.00	3.00± 0.00
Mamling	12.3±4.5 (0.0)	14.8±2.2 (0.0)	12.9±4.4	5.57±3.31
Fakchamara	9.1±1.9 (27.8)	26±6.4 (55.5)	19±6.0	4.58±2.40

2.1.1.1 *Live weight*

Estimates of live weight were made only on the first visit, derived from measurements of the animals (Plate 2.1), using the following equation of Yazman (1987):

$w=(lg^2/300)/2.2$

Where, w= live weight in kg

l = length from collar bone to hip bone in inches

g = girth measured on the chest in inches

Plate 2.1 Farmers assisting to take measurement of animals

2.1.1.2 *Feed offered and refused*

Farmers were requested to present the fodder for the next day's feeding so that these foods could be weighed. Each enumerator was provided with a spring balance (4.00 kg capacity). The concentrate *'khole'* being fed was carefully examined and its content discussed with members of the family. The refusals were visually inspected for content and weighed. Each farmer was requested to keep any left over feeds for each animal separately, which were later weighed.

2.2.4.6 *Feed sampling and analysis*

At each visit, farmers were asked their opinions about the quality of feeds that they were using. Samples were collected from the loads of feed being fed to the animals. Representative sub-samples of supplementary feeds and the basal diet were collected. The collected fresh samples on the farm were transported immediately to the laboratory. Upon receiving the feed samples in the laboratory, the leaves of tree fodder were wiped to remove any visible surface contaminants such as pest eggs, bird droppings, dust and soil deposits. In the laboratory, plant materials were chopped and dried at 60 ±3°C in a forced hot air oven to a constant weight, and the dry matter was determined. Samples were analysed in duplicate. Mean results were reported from the duplicates.

Chemical data for most of the fodder was available from published literature (Subba, 1998). For other species the samples were dried and ground to pass through a 1 mm mesh sieve for the determination of crude protein (CP), total ash (TA) and ether extract (EE), lignin and acid detergent insoluble nitrogen (ADIN). Crude protein, total ash and ether extract were determined by conventional techniques. Lignin and ADIN were determined as per the technique described by Van Soest and Robertson (1985).

Metabolisable energy (ME) (Mj kg^{-1} DM) values of most tree fodders were taken from the literature (Subba, 1998). ME of grasses and the tree fodders that were unavailable in the literature were subjected to laboratory analysis and calculation using the following equations:

$NCD=103-1.2TA-2.07L$ (Subba, 2000)

$ME=0.25EE+0.14NCD$ (De Boever *et al.*, 1988)

Where NCD, TA and EE are the neutral cellulase digestibility, lignin, total ash and ether extract respectively.

Metabolisable energy (ME) and digestible crude protein (DCP) of dry roughages and *khole* ingredients were taken from the literature (Subba, 1998, Ranjhan, 1998 and Anon, 1993).

The difference between ADIN and CP was assumed to be DCP. Acid detergent insoluble nitrogen (ADIN) and CP of tree fodders were derived from the literature (Subba, 1998). Those unavailable were determined in the laboratory. However, DCP (%) in grasses was calculated from the following equation derived for mixed grasses by Sharma *et al.* (1988):

DCP=3.87+CP (%)

2.2.4.7 Intake calculations

2.2.4.7.1 Dry matter intake

Fresh weight of tree leaves, dry roughages, grasses and *khole* was converted into dry matter intake using the average dry matter (%) of each of these components. The dry matter of dry roughages and *khole* was calculated from estimated proportions of the components that they contained. Intake of dry matter per animal per day was then calculated for cows, buffalo, oxen and calves.

To calculate the intake for each season, the 12 months were grouped according to the availability of grasses into dry and wet seasons. The wet season included the five Nepali months from Asar to Kartik (roughly June to October) and the dry season the seven Nepali months from Mangsir to Jestha (roughly November to May).

2.2.4.7.2 Digestible crude protein and metabolisable energy intake

Based on dry matter intake data for each of the main four dietary components, average diets by site and livestock type were calculated. Digestible crude protein and metabolisable energy intakes of these diets were estimated by multiplying dry matter intake of the four main components by the appropriate DCP and ME values and then summing these to give an overall value for the diet concerned.

Tree fodder and grasses

Digestible crude protein and ME from tree fodders and grasses were estimated by multiplying DM intake of these components by the factors derived from the laboratory analysis. Digestible crude protein factors used for tree fodder and grasses were 9.40% and 8.38% respectively whilst the ME factors used were 8.10 and 2 MJ kg-1 DM. The same factors were used for all sites.

For dry roughages and khole, differences between sites in the proportions of materials used to make up these components were observed and it was therefore necessary to calculate site-specific multipliers as described below.

Dry roughages

Intakes of DCP and ME were calculated from the estimated proportions of rice straw, wheat straw, millet straw, maize sheath and maize stover used at individual sites (the proportion was considered the same for all animal types within a site). Factors thus derived for DCP and ME for each site (Table 2.2) were used to convert the DM dry roughage intake (kg) into DCP and ME for all animal types and study sites.

Table 2.2 Factors used to convert DM dry roughage intake (kg) into DCP and ME

Site	DCP	ME
Fakchamara	0.55	5.16
Fikkal	0.14	4.47
Mamling	0.39	4.88
Sindhuwa	0.59	4.86
Patle	0.43	4.92

Khole

Intakes of DCP and ME were calculated from the estimated proportions of these components (mustard cake, rice bran, maize flour, others (including waste vegetables, grasses and weeds)) used at individual sites (the proportion was considered the same for all animal types within a site). Factors thus derived for DCP and ME for each site (Table 2.3) were used to convert the *khole* DM intake (g $head^{-1}$ day^{-1}) into DCP (g) and ME (MJ $head^{-1}day^{-1}$) intake for all animal types and study sites.

Table 2.3 Factors to convert *khole* intake (g) into DCP (g) and ME (MJ)

Site	DCP	ME
Fakchamara	4.0×10^{-2}	9.6×10^{-6}
Fikkal	5.9×10^{-2}	14.0×10^{-6}
Mamling	3.6×10^{-2}	8.2×10^{-6}
Sindhuwa	4.3×10^{-2}	8.3×10^{-6}
Patle	7.1×10^{-2}	12.2×10^{-6}

2.2.4.8 *Data collation and statistical analysis*

Data were subjected to analysis of variance using the General Linear Model (GLM) procedure in the Minitab statistical program (Minitab for Windows 2000, release 13.31). The analysis was carried out for each feed type and animal type separately with fixed factors of site and season. Dry matter intake of the calves of cattle and buffalo were amalgamated as one animal type for ease of analysis.

2.2.5 Tree fodder inventory

An inventory of the fodder trees present on participating farms was made to characterise the availability of fodder tree species to households. The inventory was also intended to quantify the contribution of tree fodders to meeting the dry matter need of animals during the winter dry season, when other sources of green fodder are unavailable. In conjunction with the survey and monitoring data, this allowed assessment of tree fodder resources on farm in relation to the requirements of the animals that have to be maintained.

2.2.5.1 *Design of data sheets*

Forms to record the fodder trees included three different sheets for information on fodder trees on *bari* land, *khet* land and forest or waste land. For individual trees, the following data were recorded: a qualitative assessment of size (large tree, small tree or shrub), age, the period during which leaves of the tree could be used for fodder and a qualitative assessment by the farmer of foliage yield. The format also asked farmers to state the flushing and leaf shedding seasons of the tree species encountered.

2.2.5.2 *Data collection*

The enumerators who were involved in the longitudinal monitoring also carried out the inventory of tree fodders. Data collection was carried out between September and November, at the time when the farmers began supplying tree fodders to their animals, in response to gradually diminishing production of grasses. Members of the household aided in the recording process as they were involved in identification of their land and the species of tree fodders present within their farm premises. Farmers and enumerators discussed and estimated the yield of individual trees.

2.2.5.2.1 *Estimated fodder yields*

The yields were estimated in local terms such as *bhari* tree^{-1} year^{-1} and then converted to standard units (1 *bhari* is equivalent to 35 kg). The data recorded for individual trees was compiled for each farm and tabulated in a spreadsheet using Microsoft Excel. Actual Fodder Supply (AFS kg year^{-1}) was calculated based on the following approximation:

a.) Fodder yield from bamboo species was estimated as 50% of total biomass (25% of bamboo biomass cannot be harvested whilst about 25% is stems or inedible) and *amliso* (*Thysanolaena maxima)* was estimated as 75% of total biomass (approx. 25% are stems and inedible).

b.) Actual fodder supply (kg day^{-1}) was estimated from annual AFS based on 210 days representing the seven month long dry season.

2.2.5.2.2 Estimated tree fodder balance

Fodder yield and balance of fodder supply was calculated based on the current number of animals in each site and the dry matter requirement for the average large ruminant of 3.5 to 5.5 kg DM d^{-1} for animals weighing 200 –350 kg (Ranjhan, 1998).

2.3 Results

2.3.1 Farm characterisation

2.3.1.1.1 Land holding

Total farm area varied from 1.24 to 2.56 ha, with high variation around mean areas of each land type at each site (Figure 2.2).

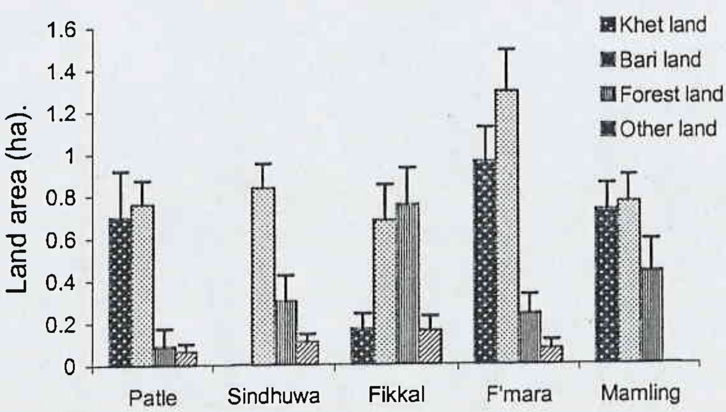

Figure 2.2 Mean land holding of the farmers at each study site (n=15) in ha (bar is SEM). *Bari* refers to non-irrigated cultivated land generally on upper slopes, *khet* to irrigated terraces on lower slopes. Forest land includes cardamom plantations, which were only encountered in Fikkal. Other land includes land unsuitable for cultivation, grazing areas and tea plantations that were only encountered in Fikkal.

Bari land was the predominant land type across all sites while *khet* land was also important in Patle, Fakchamara and Mamling. Forest land was an important category in Fikkal because there were substantial areas of cardamom but generally there was little privately owned forest or grazing land. There are collectively owned forest and grazing areas at all sites that were not surveyed here.

2.3.2 Contribution of fodder types

Although there was considerable variability amongst farms, grasses made the largest contribution to animal diets at all sites, followed by trees and then roughages (Figure 2.3). The amount of fodder from grasses and dry roughage was significantly different between sites ($p<0.05$) but the contribution of tree fodder was similar across sites.

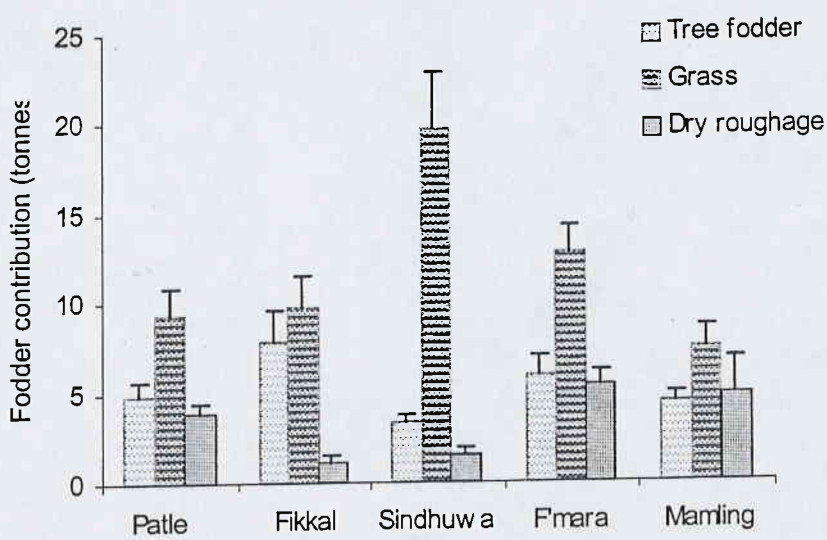

Figure 2.3 Farmers' assessment of amounts of fodder (tonnes) contributed by different types of fodder at each study site (bar is SEM)

2.3.3 Distribution of different feeds by land types

Bari land was by far the most important source of all fodder types, contributing over 80% of grass and over 60% of dry roughages and tree fodder (Figure 2.4). About a third of dry roughage was contributed by *khet* land, generally in the form of rice straw. Forest land contributed a little over a quarter of the tree fodder used on farms.

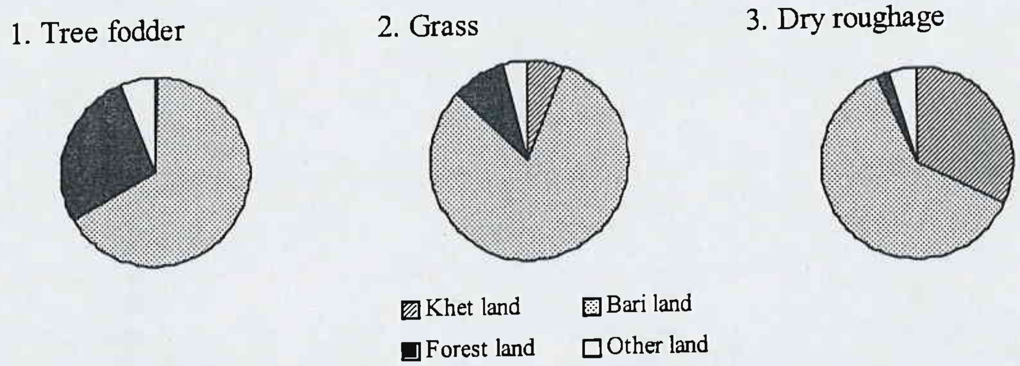

Figure 2.4 Mean contribution to total fodder supply for each major fodder type by land type (%) for farms across all sites (n=75).

2.3.4 Livestock populations

Animal numbers varied from year to year (Figure 2.5). Analysis of variance of the pooled data across sites and breeds showed that there was significant difference between

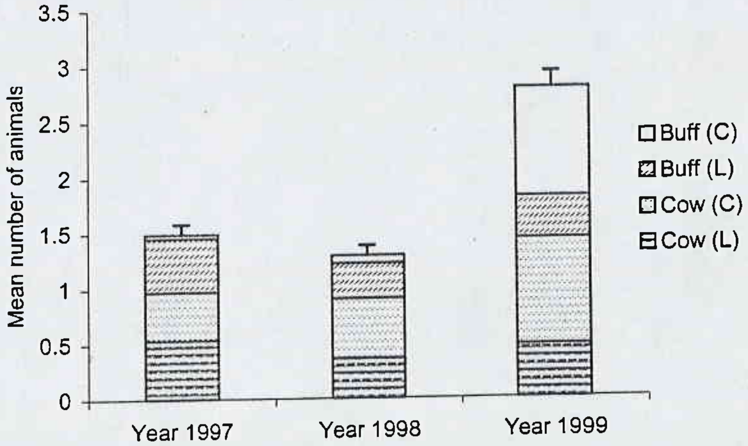

Figure 2.5 Mean numbers of local and exotic cattle and buffalo per household across all sites (n=75) from 1997 to 1999 (bar is SEM)

years ($p<0.01$) for the total number of animals (cattle and buffalo), there were also significant differences ($p<0.001$) between breeds and a significant interaction between breeds and years ($p=0.01$). The number of local animals dropped in 1998 but increased again in 1999 whilst there was a steady increase in numbers of exotic animals.

2.3.4.1 Current livestock holdings in the study sites

Total livestock units per farm varied little amongst sites because lower numbers of large ruminants in the less accessible sites (Fakchamara and Mamling) were compensated for by larger holdings of small ruminants. Holdings of both large and small ruminants were low in Sindhuwa and there were no small ruminants in Fikkal (Table 2.4).

Table 2.4 Average livestock holding in the study sites (figures are the average of households in each study site)

Site	Large ruminants (no. of animals)	Small ruminants (no. of animals)	Livestock unit (LSU)	% crosses (large ruminants)
Patle	2.40 (0.254)	3.00 (0.414)	3.00 (0.264)	35.6 (10.6)
Sindhuwa	2.07 (0.182)	1.00 (0.239)	2.27 (0.188)	67.8(10.5)
Fikkal	3.80 (0.500)	0.00 (0.00)	3.80 (0.500)	96.3 (2.6)
Fakchamara	2.80 (0.312)	3.53 (0.742)	3.51 (0.358)	9.4 (4.4)
Mamling	2.73 (0.396)	5.20 (2.04)	3.77 (0.495)	8.3 (6.8)
Average			3.21	

Large ruminants= cattle & buffalo (Fikkal data is for cattle only)

Small ruminants = sheep & goats

Conversion factors of large and small ruminants into livestock unit (LSU) was made using the following assumption: 1 sheep or goat = 0.2 cattle or buffalo, agreed among a group of participating farmers on the basis of their experience that a sheep or goat can eat 1/5 of that eaten by a cow or buffalo.

The low numbers of crossbred animals in Fakchamara and Mamling are mainly buffalo. In Sindhuwa and Patle, the crossbreds are mainly cattle, although some crossbred buffalo can also be seen. The cows in Fikkal are entirely crossbred individuals.

Average holdings of different types of large ruminants at each of the study sites are presented in Figure 2.6.There was a significant effect of site on holding of sheep and goats (p=0.004), cows (p<0.001) and oxen (p=0.001). It was clear that farmers at more accessible sites tended to keep more cows than those in the more inaccessible areas. Conversely, the farmers in inaccessible areas tended to hold more oxen.

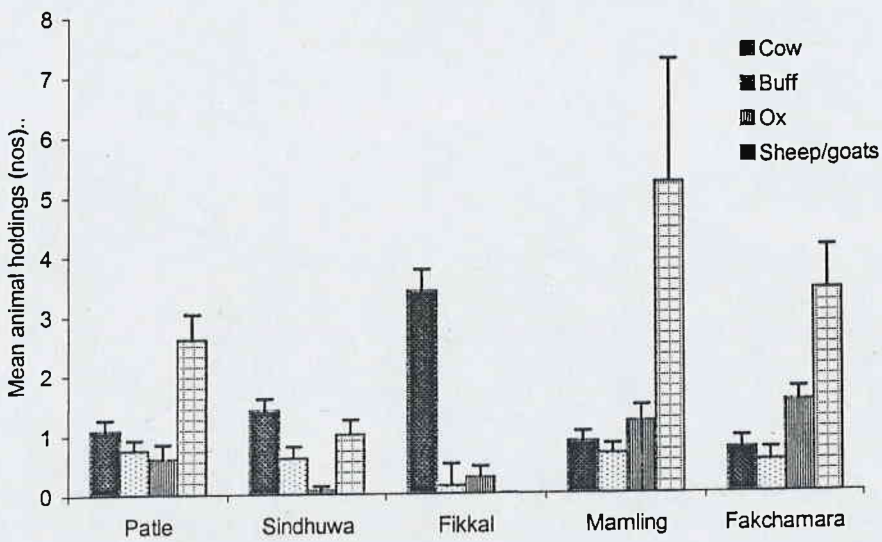

Figure 2.6 Mean holding of animal species in study sites (bar is SEM)

2.3.5 Productivity status of lactating animals

2.3.5.1 Milk and ghee production

Both milk (p<0.05) and ghee (p<0.01) yields were significantly affected by site. No year-to-year variation in the milk or ghee yield was observed when the data were analysed for a 3-year period. However there was a significant interaction between site and year (p<0.05) on milk production. This indicated that the milking animals behaved differently with respect to the site and year. Average milk and ghee yield in the study sites (from the pooled data of years 1997, 1998 and 1999) are shown in Figures 2.7(a) and 2.7(b) respectively.

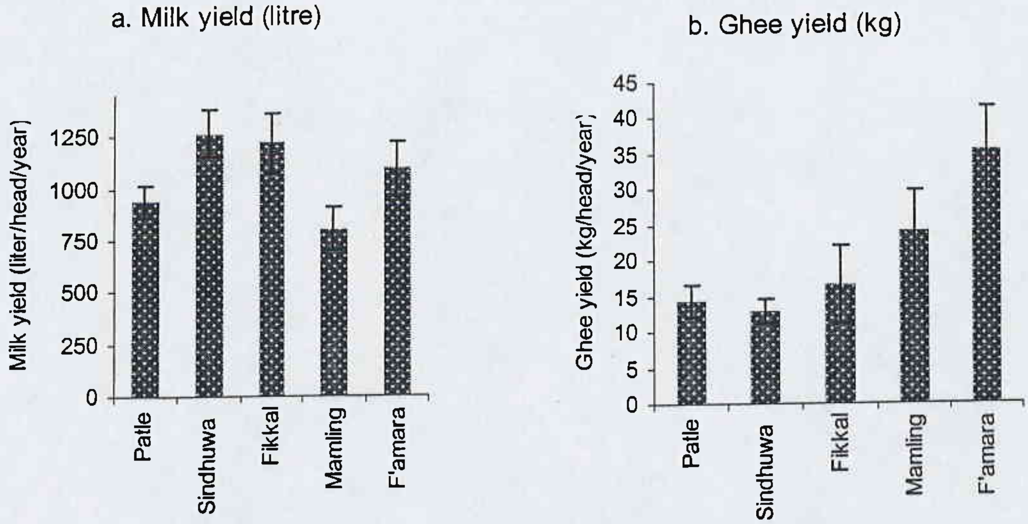

Figure 2.7 Average milk and ghee productivity of cow or buffalo per head per year. (a.) Milk yield (litre), site effect significant at $p<0.05$ (b.) Ghee yield (kg), site effect significant at <0.01)

There is an indication of higher milk yield in accessible areas (Patle, Sindhuwa and Fikkal) compared to inaccessible areas (Mamling and Fakchamara); Figure 2.7(a), while it is clear that ghee yield is higher in the areas with poor access (Figure 2.7(b)).

2.4 Longitudinal monitoring

2.4.1 Amount and composition of different feed types

The major feed types supplied by the farmers in the eastern middle hills are tree fodders, grasses, dry roughages and *khole*. On average about 19% of the total feed intake (mean of all animals, across all sites for the whole year) was contributed by tree fodders and this was fairly consistent amongst animal types, varying from about 17% for oxen to almost 22% in cows (Figure 2.8). However, during the dry season (roughly from mid November to mid May), about 28% of the total drymatter intake (mean for all animals) of the dry season was contributed by tree fodder. Intake rates of *khole* were notably higher for milking animals (cows and buffalo) and calves while oxen received a higher proportion of dry roughage than other animal types.

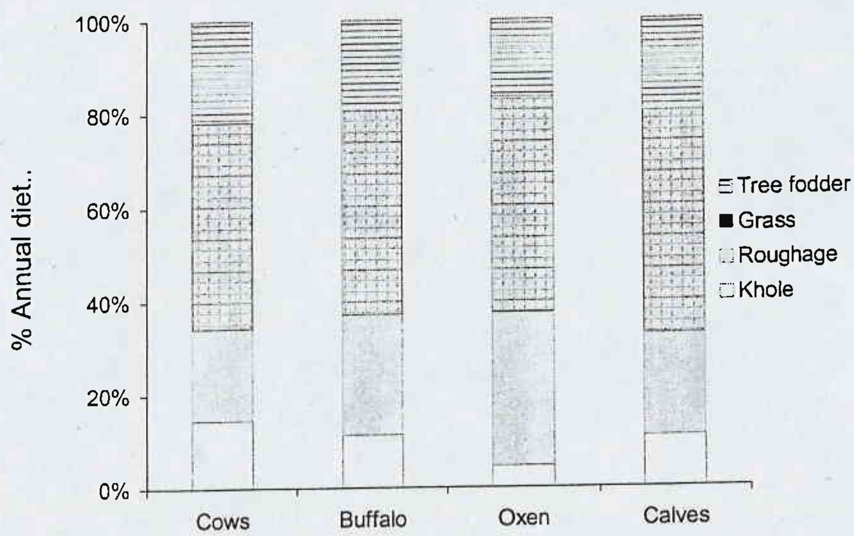

Figure 2.8 Mean composition of total diets received by different animal types across all sites.

The composition of diets altered with season (Figure 2.9). The intakes of tree fodder and dry roughages were significantly higher in the dry season ($p<0.001$) whilst the intake of grass was significantly higher in the wet season. Although the proportion of *khole* was slightly higher (53%) in the dry season compared to the wet season (47%), the difference was not significant.

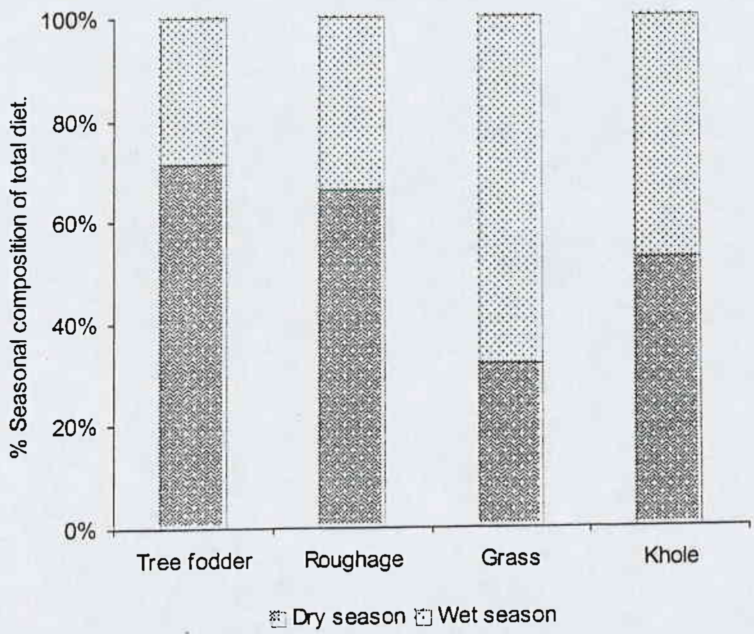

Figure 2.9 Composition of fodder types by dry and wet seasons

2.4.1.1 *Tree fodders*

A total of 34 different tree species were reported to be commonly cultivated and maintained by farmers on their farmland. A list of the most commonly cultivated species of trees is given in appendix 2.3 and the fodder yield in appendix 2.4.

2.4.1.2 *Dry roughages*

The most common roughages encountered were rice straw, millet straw, maize sheath and maize stovers. Resource rich farmers, who had private forest or waste land, also maintained thatch grasses, locally referred to as *khar*, which are cut and fed dry. However, none of the farm participants in Fikkal and Mamling reported that they maintained dry grass for winter-feeding. A small amount of thatch grasses (comprising 1% of the dry roughages) were fed in Patle, where they were mainly supplied to oxen. Dry roughages formed an important source of the entire year dry matter sources. Rice straw was the most commonly used dry roughage at all the study sites. The contribution of rice straw varied from about 50% in Fikkal and Fakchamara to a maximum of about 70% in Mamling. Distribution of millet straw, maize sheath and maize stover was fairly similar in all the sites except for maize sheath and maize stover in Mamling and millet straw in Sindhuwa. However, no distinct pattern of distribution of dry roughages was seen with regard to the difference in accessibility. Average proportions of dry roughages used at each study site are given in Figure 2.10

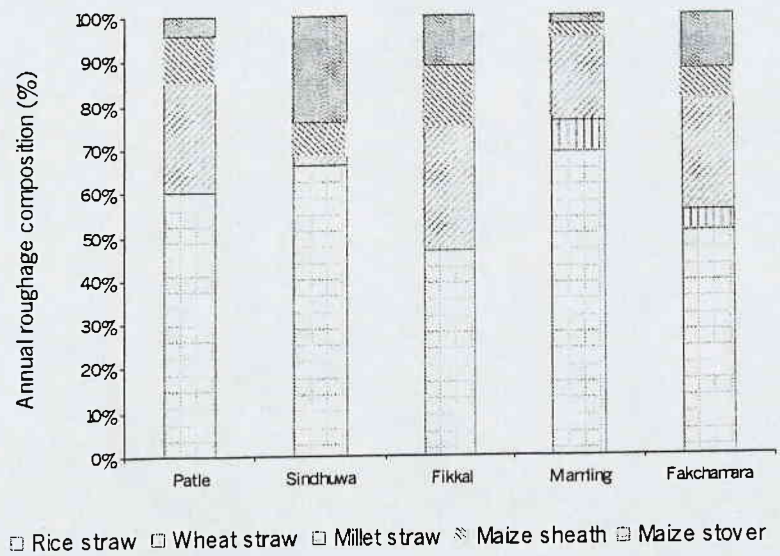

Figure 2.10 Average proportions of dry roughages used by each site

2.4.1.3 *Grasses*

A total of 33 different species of grasses were available and were actually offered to the animals during the wet season (appendix 2.5). *Salimbo* (botanical name unknown), *furke khar* (botanical name unkown) and *banso* (*Eragostis tennella*) contributed 13%, 11% and 10% respectively, whilst *lekali hade*, *udase* and *siru* (*Imperata spp.)* each contributed about 8% to the total supply of grasses. Maize thinnings represented about 6% of the total intake of grass. Various synonyms for ferns were noted in the study sites. Although *unieu* is the common name for fern at all study sites several other names for ferns including *pire unieu, rani unieu, buchke unieu, kali unieu* and *niguro* were encountered in different places.

2.4.1.4 *Khole*

A variety of ingredients were used for making *khole* (a boiled local concentrate). Cereal by-products (rice bran, maize flour, wheat bran, maize and rice grits), legume haulms, mustard cake, vegetable tops and assorted vegetables are the major ingredients for *khole.* Other ingredients sometimes used were weeds, seasonal grasses and young shoots of some fodder trees. The average composition of *khole* used at each study site is presented in Figure 2.11.

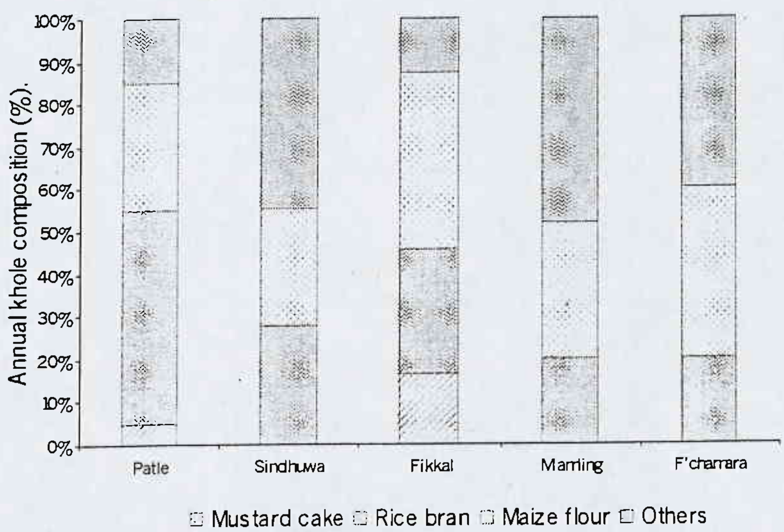

Figure 2.11 Composition of *khole* at different sites

In Mamling *khole* comprised about 650 g of milling by-products (maize flour 400 g and rice bran 250 g), and about 600 g grasses and crop residues. About 10 g of mustard cake was supplemented to the *khole* and this was limited to two farmers who only used it during the dry season. In Fakchamara no mustard cake was supplemented. Milling by-products contributed about 1 kg to the *khole* supply. The remainder (about 800 g) was supplied from crop residues and vegetable wastes. In Fikkal approximately 400 g mustard cake, 700 g rice bran, and 1.2 kg maize flour and 100 g grasses, weeds and vegetables contributed to the total daily intake of *khole* in cows. All the farmers provided mustard cake at a more or less similar rate through out the year. In Sindhuwa, the intake of *khole* in cows and buffalo was contributed by 500 g each of rice bran and maize flour and the rest (about 800 g) was derived from weeds, grasses and vegetable wastes. In Patle, the amounts of mustard cake, rice bran and maize flour used were 100 g, 1 kg and 600 g respectively. The contribution of weeds, grasses and vegetable wastes was about 300 g.

2.4.2 DRY MATTER INTAKES FROM DIFFERENT FEEDS AND THEIR CONTRIBUTION TO THE TOTAL DMI, DCP AND ME

2.4.2.1 TREE FODDER

2.4.2.1.1 DRY MATTER FROM TREE FODDER

The dry matter intake (DMI) of tree fodder was higher in cows and buffalo than in oxen ($p<0.05$). There was slightly higher intake of tree fodder dry matter by cows at Fikkal and buffalo in Mamling but the intake of tree fodder dry matter was only significantly different among sites for oxen (Table 2.5). Tree fodder DMI was significantly higher ($p<0.05$) in oxen at Mamling compared to the other two sites, Patle and Fakchamara.

Table 2.5 Mean dry matter intake of tree fodder (kg $head^{-1}.day^{-1}$) of tree fodder by all animal types across all study sites. Standard errors in brackets. Buffalo and oxen were not encountered at Fikkal during the study.

Site	Cows	Buffalo	Oxen	Calves
Patle	2.45 (0.236)	2.31 (0.644)	1.04 (0.404)	2.25 (0.552)
Sindhuwa	2.37 (0.535)	2.17 (0.541)	-	0.70 (0.970)
Fikkal	3.63 (0.338)	-	-	1.69 (0.299)
Mamling	2.08 (0.334)	3.29 (0.624)	2.44 (0.323)	1.96 (0.402)
Fakchamara	1.76 (0.438)	2.07 (0.604)	1.03 (0.365)	0.91 (0.416)
Significance of site effect	NS	NS	*	NS

Figure in parenthesis is the SEM, * site effect significant at $p<0.05$. NS not significant

The contribution of tree fodders to the total DMI was broadly similar for cows, buffalo and oxen in all sites. However tree fodder appeared to form a larger portion of intake for cows in Fikkal and for buffalo and oxen in Mamling. In the case of calves, this contribution was the lowest in Sindhuwa (9%) and highest in Fikkal (28%) (Table 2.6).

Table 2.6. Contribution of tree fodder (%) to the total DMI of animal types across all study sites

Site	Cows	Buffalo	Oxen	Calves
Patle	19.57	17.46	11.48	23.15
Sindhuwa	19.18	19.06	-	8.91
Fikkal	35.49	-	-	28.43
Mamling	18.35	24.60	26.77	23.47
Fakchamara	16.35	15.97	11.60	14.95

Because of the abundance of cut grasses, use of trees during the wet season was minimal. The intake of tree fodder during the dry season was significantly higher than the wet season for all animal types except for oxen (Table 2.7). Over 70% of the total annual tree fodder DM intake took place during the dry season.

Table 2.7. Mean dry matter intake of tree fodder (kg $head^{-1}.day^{-1}$) as affected by season for all animal types (standard error in brackets).

Animal species	Dry	Wet	Significance of season effect
Cows	3.48 (0.363)	1.43 (0.513)	**
Buffalo	3.39 (0.367)	1.53 (0.520)	**
Oxen	1.85 (0.296)	1.18 (0.411)	NS
Calves	2.61 (0.298)	0.61 (0.402)	***

Figure in parenthesis is the SEM; ** and *** site effect significant at $p<0.01$ and $p<0.001$ respectively. NS not significant

2.4.2.1.2 DCP AND ME FROM TREE FODDER

Tree fodder was an important source of protein and energy to supplement low quality dry roughages. Of the total intakes of metabolisable energy (ME) and digestible crude protein (DCP) (mean for all animals at all sites), the percent contribution from tree fodder was about 33% of energy and 16% of DCP on an annual basis whilst, about 57% of ME and about 27% of DCP during the dry season. Analysis of data by site revealed that the contribution from tree fodder to total ME ranged from 27% in Fakchamara to about 39% in Mamling. In the case of DCP, the contribution from tree fodder ranged from about 12% in Patle to about 25% in Mamling.

2.4.2.2 *DRY ROUGHAGES*

2.4.2.2.1 DRY MATTER FROM DRY ROUGHAGES

Intakes of dry roughages (kg dm head^{-1}.day^{-1}) were significantly different ($p<0.05$) amongst large animal types. Intake of roughages by cows was significantly lower than by buffalo and oxen. Analysis of data by site showed a marked difference in the intake of dry roughages among sites for cows ($p<0.001$), buffalo ($p<0.01$) and calves ($p<0.01$) but not oxen (Table 2.8). In the case of cows, the intake of dry roughages was markedly high in Patle and Fakchamara but was markedly low in Fikkal. The intake of dry roughages by buffalo was more or less similar for Patle, Mamling and Fakchamara but markedly lower in Sindhuwa. Like cows, the intake of dry roughages by calves was low in Fikkal compared to the other sites.

Table 2.8 Mean dry matter intakes of dry roughages (kg head^{-1}day^{-1}) by all animal types across all study sites. Buffalo and oxen were not encountered at Fikkal during the study.

Site	Cows	Buffalo	Oxen	Calves
Patle	3.63 (0.417)	3.54 (0.507)	2.88 (0.543)	2.64 (0.450)
Sindhuwa	1.06 (0.335)	1.53 (0.524)	-	1.34 (0.790)
Fikkal	0.45 (0.217)	-	-	0.24 (0.397)
Mamling	2.86 (0.315)	4.31(0.517)	2.64 (0.530)	2.758 (0.390)
Fakchamara	3.40 (0.413)	4.00 (0.553)	3.39 (0.334)	1.72 (0.442)
Significance of site effect	***	**	NS	**

Figures in parenthesis are the SEM; ** and *** site effect significant at $p<0.01$ and $p<0.001$ respectively. NS not significant

The contribution of dry roughages to the total DMI was markedly low in Fikkal for cows and calves. In general, this contribution was higher in the less accessible sites (Mamling and Fakchamara) for all animal types (Table 2.9) although at Patle dry roughage % was also relatively high.

Table 2.9. Contribution of dry roughages (%) to the total DMI of animal types across all study sites

Site	Cows	Buffalo	Oxen	Calves
Patle	28.87	26.82	31.83	27.6
Sindhuwa	8.62	13.44	-	17.05
Fikkal	4.41	-	-	4.04
Mamling	25.23	32.20	28.97	33.07
Fakchamara	31.60	30.91	38.19	28.29

The contribution of the dry roughages to the total dry matter intake was 32% and 16% for the dry and the wet season respectively. On average, animals received 66% of the total dry roughages during the dry season. The intake of dry roughage was significantly lower in the wet season ($p<0.001$) than the dry season. This effect was significant for all animal types (Table 2.10).

Table 2.10 Mean dry matter intake of dry roughages (kg $head^{-1} day^{-1}$) as affected by season for all animal types.

Animal species	Dry season	Wet season	Significance of season effect
Cows	2.83 (0.298)	1.73 (0.421)	*
Buffalo	4.08 (0.374)	2.61 (0.529)	*
Oxen	3.94 (0.350)	2.01 (0.487)	**
Calves	2.70 (0.306)	0.88 (0.432)	**

Figure in parenthesis is the SEM; * and ** season effect significant at $p<0.05$ and $p<0.01$ respectively.

2.4.2.2.2 DCP AND ME FROM DRY ROUGHAGES

Of the total intakes of ME and DCP (average over all animals in all sites), the percent contribution to ME from dry roughages was about 22% whilst the contribution to DCP intake was below 1% on an annual basis. Analysis of data by study sites revealed that the contribution of dry roughages to the ME was from about 3% in Fikkal to about 36% in Fakchamara. Of the total DCP intake, the contribution from dry roughages was below 2% in all sites.

2.4.2.3 GRASSES

2.4.2.3.1 DRY MATTER FROM GRASSES

Intakes of dry matter of grasses were relatively high for cows, buffalo and calves at Sindhuwa and relatively low for cows and calves at Fikkal. There were significant differences between study sites for grass intakes of cows and buffalo whilst intake was not significantly different by site for oxen and calves (Table 2.11).

Table 2.11 Mean dry matter intake of grasses (kg $head^{-1}.day^{-1}$) by all animal types across all study sites. Buffalo and oxen were not encountered at Fikkal during the study.

Site	Cows	Buffalo	Oxen	Calves
Patle	4.53 (0.458)	5.19 (0.795)	4.68 (0.540)	3.93 (0.811)
Sindhuwa	7.12 (0.779)	6.50 (0.745)	-	5.42 (0.765)
Fikkal	3.79 (0.569)	-	-	2.51 (0.719)
Mamling	5.00 (0.458)	4.59 (0.791)	3.49 (0.650)	2.88 (0.320)
Fakchamara	4.83 (0.678)	5.63 (0.891)	4.24 (0.840)	3.11 (0.795)
Significant of site effect	***	**	NS	NS

Figure in parenthesis is the SEM; ** and *** site effect significant at $p<0.05$ and <0.01 respectively. NS not significant

The proportion of grasses in livestock diets was high during the wet season, when 66% of the annual grass eaten by animals (Figure 2.9). The contribution of grasses in the dry season was 29% of the total dry matter intake. These grasses were derived mainly from nearby riverbanks, private or government forests, community forests and wastelands.

The contribution of grasses to the total DMI was markedly high at Sindhuwa for cows, buffalo and calves and for oxen at Patle. The contribution was more or less similar in other sites (Table 2.12).

Table 2.12. Contribution (%) of grass to the total DMI of animal types across all study sites

Site	Cows	Buffalo	Oxen	Calves
Patle	36.03	39.32	51.69	40.43
Sindhuwa	57.69	57.07	-	68.96
Fikkal	37.04	-	-	42.26
Mamling	44.17	34.30	38.34	34.53
Fakchamara	44.82	43.51	47.66	51.15

Although the intake of grasses was higher in buffalo and cows compared to oxen, no significant difference was found amongst animal types. Analysis of data by season revealed that season had a significant effect on the grass dry matter intake for all animal types (Table 2.13). In the dry season the grass dry matter intake was significantly lower than in the wet season.

Table 2.13 Mean dry matter intake of grasses (kg.head^{-1}.day^{-1}) as affected by season for all animal types.

Animal species	Dry season	Wet season	Significance of season effect
Cows	3.38 (0.677)	8.33 (0.96)	***
Buffalo	4.02 (0.806)	8.92 (1.14)	**
Oxen	2.03 (0.672)	6.24 (0.931)	**
Calves	1.31 (0.408)	4.94 (0.578)	***

Figure in parenthesis is the SEM; ** and *** season effect significant at $p<0.01$ and <0.001 respectively

2.4.2.3.2 DCP AND ME FROM GRASSES

Of the total intakes of metabolisable energy (ME) and digestible crude protein (DCP) (average over all animals in all sites), the percent contribution from grasses was about 18% of energy and 31% of DCP on an annual basis. Analysis of data by study sites revealed that the contribution from grasses to the ME was from about 11% in Fikkal to about 30% in Sindhuwa. Likewise, the contribution of DCP from grass was from about 16% in Fikkal to about 48% in Fakchamara.

2.4.2.4 KHOLE

2.4.2.4.1 *DRY MATTER FROM* KHOLE

Intake of khole by cows and buffalo was significantly different between study sites ($p<0.001$). In general, the intake by cows was generally higher in accessible sites (Patle, Sindhuwa and Fikkal) compared to the less accessible sites (Fakchamara and Mamling) (Table 2.14). In the case of buffalo, although the intake was high in one accessible site (Patle), the intake in another accessible site (Sindhuwa) was similar to the less accessible sites (Mamling and Fakchamara). No general trend of intake by oxen was observed by accessibility. Although the intake by calves in accessible sites (Patle and Fikkal) was higher than in less accessible sites (Fakchamara and Mamling), the intake in Sindhuwa (accessible site) was more or less similar to less accessible sites.

Table 2.14. Mean dry matter intake of *khole* (kg head^{-1}.day $^{-1}$) by different animal types for each study site. During the study oxen and buffalo were not encountered in Fikkal and oxen were not encountered in Sindhuwa.

	Cows	Buffalo	Oxen	Calves
Patle	1.97 (0.118)	2.16 (0.113)	0.46 (0.148)	0.90 (0.072)
Sindhuwa	1.79 (0.148)	1.19 (0.143)	-	0.40 (0.339)
Fikkal	2.36 (0.123)	-	-	1.50 (0.050)
Fakchamara	1.39 (0.153)	1.19 (0.149)	0.54 (0.114)	0.74 (0.400)
Mamling	0.78 (0.138)	1.24 (0.141)	0.23 (0.144)	0.34 (0.071)
Significance of site effect	***	***	NS	NS

Figure in parenthesis is the SEM; *** site effect significant at <0.001. NS not significant

Intake of *khole* (kg DM head $^{-1}$.day $^{-1}$) significantly differed amongst animal types. The intake was significantly lower ($p<0.001$) in oxen compared to buffalo and cows.

The contribution of *khole* to the total DMI for cows, buffalo and calves was generally higher in the accessible sites (Fikkal, Patle and Sindhuwa) than the less accessible sites (Mamling and Fakchamara). The contribution of *khole* to the total DMI for oxen was lower than the other animal types in all sites.

Table 2.15. Contribution of *khole* (%) to the total DMI of animal types across all study sites

Site	Cows	Buffalo	Oxen	Calves
Patle	15.66	16.37	5.04	9.26
Sindhuwa	14.49	10.41	-	5.09
Fikkal	23.09	-	-	25.25
Mamling	12.29	8.92	5.94	8.87
Fakchamara	7.21	9.61	2.54	5.59

Khole was offered both in dry and wet seasons, with overall intake slightly higher in dry season than in wet season (53% vs 47%) (Figure 2.9). However, the intake of khole between the dry and wet season was not significantly different by animal type except for calves (Table 2.16).

Table 2.16 Intake of *khole* as affected by season for all animal types

Animal spp.	Dry season	Wet season	Significance of season effect
Cows	1.67 (0.119)	1.65 (0.958)	NS
Buffalo	1.43 (0.105)	1.46 (0.871)	NS
Oxen	0.29 (0.996)	0.53 (0.153)	NS
Calves	1.18 (0.182)	0.53 (0.257)	*

* Season effect significant at $p<0.05$. NS not significant

2.4.2.4.2 DCP AND ME FROM KHOLE

Of the total intakes of ME and DCP (average over all animals in all sites), the percent contribution from khole was about 27% of ME and about 52% of DCP on an annual basis. Of the total ME intake, the contribution from khole ranged from from about 14% in Fakchamara to about 48% in Fikkal. Of the total DCP inake, the contribution from khole was from 33% in Fakchamara to about 69% in Fikkal.

2.4.3 Intakes of different feed types by cows, buffalo, oxen and calves in study sites

2.4.3.1 COWS

In the case of cows, intake of all the fodder types except tree fodders was significantly different amongst sites ($p<0.001$). The key differences were that more grass and less roughage was taken in Sindhuwa than the other sites, except for Fikkal (Figure 2.12). At Fikkal, the very low roughage intake was compensated for by a higher tree fodder intake than at other sites, rather than more grass. Intake rates of *khole* (kg DM $head^{-1}.day^{-1}$) were higher in Sindhuwa, Patle and Fikkal (which are the accessible sites) compared to Mamling and Fakchamara (less accessible sites). The intake of *khole* by cows was highest (about 2.5 kg DM head^{-1} day^{-1}) at Fikkal and lowest in Fakchamara (< 1 kg DM head^{-1}.day^{-1}).

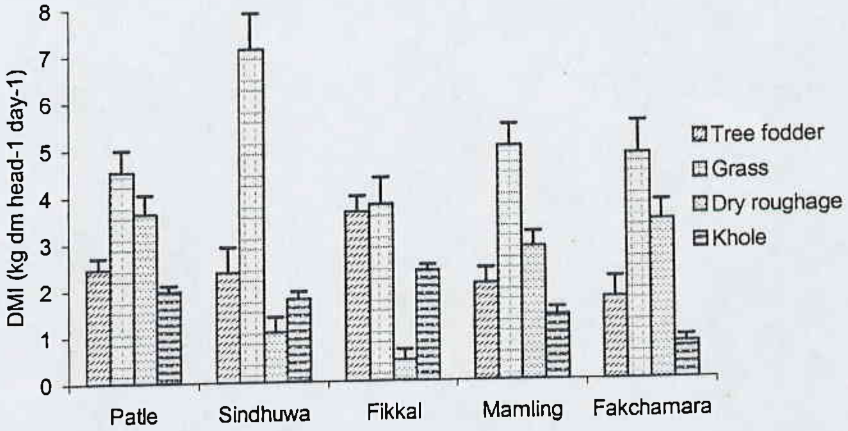

Figure 2.12 Dry matter intake (kg DM. head $^{-1}$. day $^{-1}$) (sem) of different fodders by cows in study sites (grass, dry roughages and *khole* intakes significantly different between sites at p<0.001)

2.4.3.2 BUFFALO

Intakes of grasses, dry roughages and *khole* by buffalo were significantly different among study sites (p<0.01).

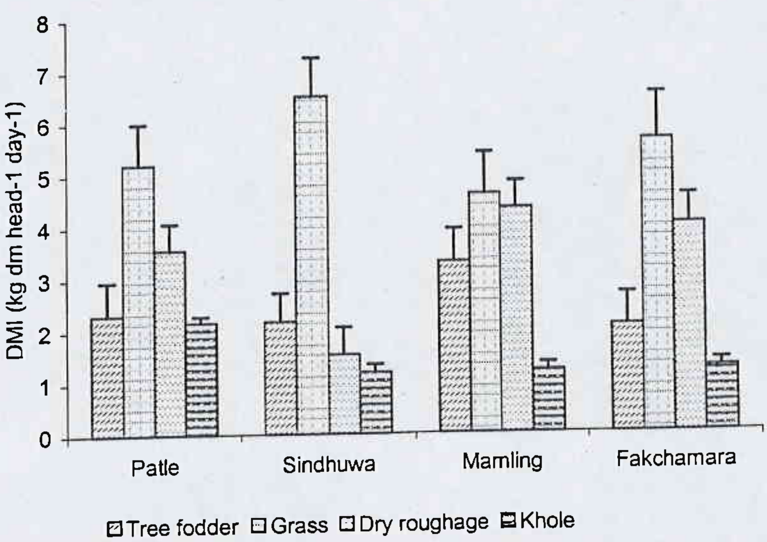

Figure 2.13 Drymatter intake (kg DM head $^{-1}$. day $^{-1}$) (sem) of different fodder types by buffalo by study sites (for grass and dry roughages there were differences between sites at p<0.01 and for *khole* at p<0.001)

The key differences, as with cows, were that the intake of grasses in Sindhuwa was markedly higher while that of dry roughages was lower than in other study sites (Figure 2.13). The intake rate of *khole* was particularly high in Patle but low in Mamling, Fakchamara and Sindhuwa.

2.4.3.3 OXEN

In case of oxen, the effect of site was significant for the intake of tree fodders ($p<0.05$) but there was no difference on the intake of grass, dry roughage or *khole* (Figure 2.14). The key differences were higher tree fodder intake and lower roughage at Mamling than the other sites and a low intake of *khole* at Fakchamara.

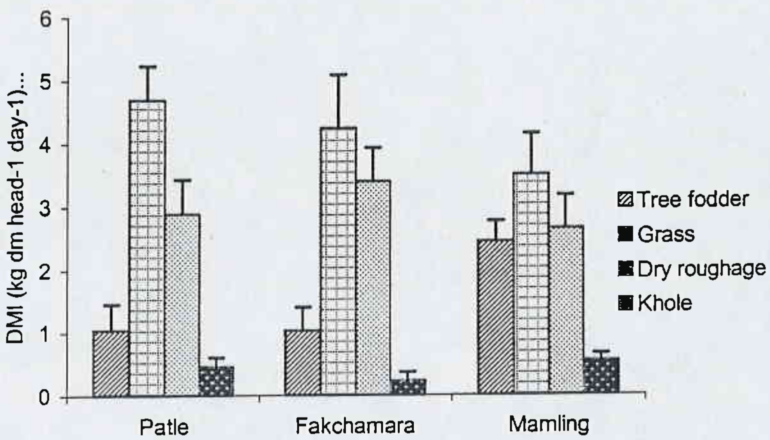

Figure 2.14 Drymatter intake (kg DM head^{-1} day^{-1}) (sem) of different fodder by oxen in study sites (only tree fodder significant $p<0.05$). There were no oxen in Fikkal and Sindhuwa during the study period.

2.4.3.4 CALVES

In the case of calves, intake significantly differed ($p<0.05$) between sites for dry roughage (Figure 2.15). The intake rate of tree fodder in Sindhuwa and Fakchamara was low (less than 1 kg DM head^{-1} day^{-1}) compared to the rest of the sites where intake rate was more or less similar. Intake rate of *khole* was low (0.34 kg DM head^{-1} day^{-1}) in Fakchamara whilst it was relatively high in Fikkal (1.50 kg DM head^{-1} day^{-1}).

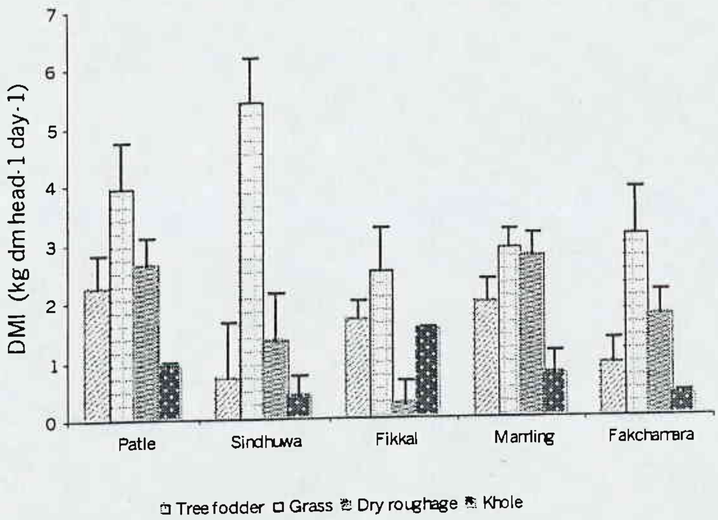

Figure 2.15 Dry matter intake (kg DM head^{-1} day^{-1}) (sem) of different fodders by calves in study sites (only dry roughage significant p<0.01)

2.4.4 Overall intake of dry matter, digestible crude protein and energy for different animal types

2.4.4.1 *Dry matter*

The overall dry matter intake (kg. head $^{-1}$. day $^{-1}$) was found to be higher than the expected for all animal types. An overview of feed dry matter intake is shown in Table 2.17. The intakes of buffalo and calves were notably higher than cows and oxen.

Table 2.17. Overall dry matter intake rates for different types of livestock

	Cows	Buffalo	Oxen	Calves
Average live weight	219 (6.12)	371 (5.49)	189 (4.55)	115 (3.18)
Total daily feed DMI (kg head^{-1}.day $^{-1}$)	11.95 (0.337)	13.45 (0.365)	8.75 (0.428)	7.53 (0.435)
Total daily feeds DMI (100^{-1}kg live wt)	3.71 (0.170)	5.70 (0.152)	4.72 (0.199)	6.72 (2.249)

Figure in parenthesis is the SEM

The mean total daily feed intake pooled for all animal types differed significantly amongst sites and seasons (p<0.05). The intakes of all fodder types individually were also significant (p<0.001) amongst the study sites. The mean total daily feed intake over the whole year for cows, buffalos and calves differed significantly amongst sites but that for buffalo and oxen did not (Table 2.18).

Table 2.18 Total daily feed intake (kg DM. head $^{-1}$. day $^{-1}$) for different livestock types at the study sites.

Animal type	Significance of site effect	Patle	Sindhuwa	Fikkal	Fakchamara	Mamling
Buffalo	NS	13.21 (0.623)	14.54 (0.623)	NA	12.89 (0.623)	13.16 (0.623)
Cows	***	12.45 (0.720)	15.24 (0.628)	10.44 (0.348)	10.62 (0.718)	11.00 (0.618)
Oxen	NS	8.61 (0.603)	NA	NA	8.63 (0.604)	8.99 (0.604)
Calves	***	10.03 (0.787)	6.54 (1.436)	5.76 (0.413)	5.84 (0.245)	9.01 (0.718)

*** Site effects significant at $p<0.001$. NS not significant

Intakes of dry matter in all animal types were not affected by accessibility except in cows. The intake of cows in accessible sites was significantly higher than sites with poor access ($p<0.05$).

There was significant influence of season on the dry matter intakes for all animal types except calves (Figure 2.16). The intake of dry matter in buffalo, cows and oxen was significantly higher in the wet season.

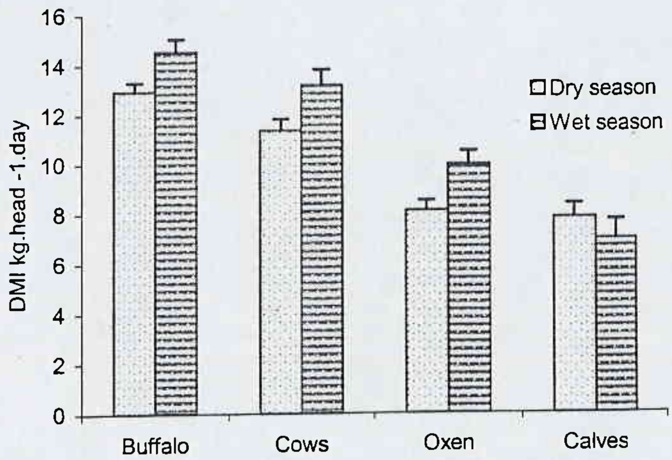

Figure 2.16 Dry matter intake by season in all animal types (significant at $p<0.05$, $p<0.05$ and $p<0.01$ for buffalo, cows and oxen respectively)

2.4.4.2 *Digestible crude protein and energy*

The estimated DCP intake of animals in all sites, particularly in calves and oxen, was lower than the recommended daily requirements for maintenance and production for Indian cattle and buffalo (Sharma, 1998). Although cows, buffalo and oxen in accessible sites in general received higher levels of DCP than those at less accessible sites, the DCP intakes of cows and buffalo at accessible sites were also just at the maintenance level of protein requirements. Except for Sindhuwa, the DCP intake of calves was higher in accessible sites than in the less accessible sites. The calves at Sindhuwa (accessible site) received DCP in amounts similar to the calves of Mamling (less accessible site). Estimated digestible crude protein ($g.day^{-1}$) in study sites for all categories of animals is given in Table 2.19.

Table 2.19 Estimated digestible crude protein ($g.day^{-1}$) in study sites for all categories of animals (calculated from the mean intake of individual dietary components for each animal type).

Site	Cows	Buffalo	Oxen	Calves
Patle	202.1	220.1	82.7	119.1
Sindhuwa	159.5	126.8	-	70.0
Fikkal	205.3	-	-	125.4
Fakchamara	89.9	118.5	56.1	49.1
Mamling	113.3	114.5	72.9	70.5

Cows and buffalo in accessible sites (Patle, Sindhuwa and Fikkal) were within the recommended daily requirements of energy for maintenance and production of Indian animal breeds (Ranjhan, 1998; Table 2.20). However, the energy intakes of cows in less accessible sites (Mamling and Fakchamara) were lower and were at the borderline of the normal requirements. Oxen in all study sites were only at a maintenance level for energy requirement whilst the calves at all sites were within the normal requirements for growth and maintenance except in Sindhuwa and Fakchamara. Calves in Sindhuwa and Fakchamara received energy at maintenance level only. Apart from cows, no general trend of energy intake was seen by accessibility (Table 2.20).

Table 2.20 Calculated ME intake (MJ.day^{-1}) in the study sites for all categories of animals (calculated from the mean intake of individual diet components for each animal type).

Site	Cows	Buffalo	Oxen	Calves
Patle	70.8	72.9	37.6	50.1
Sindhuwa	61.4	55.8	-	26.3
Fikkal	72.1	-	-	40.8
Fakchamara	48.9	60.6	36.5	25.7
Mamling	52.1	66.6	44.0	41.1

2.4.5 Tree fodder inventory

2.4.5.1 Tree populations

2.4.5.1.1 By land type and tree species

At each site, the number of trees was higher for larger land holdings. This was confirmed by a linear relationship ($y=8.144x-86.45$, $r^2=0.94$) between bari land holding size and tree numbers. Farmers in Patle possessed the highest number of tree species whilst Sindhuwa farmers possessed the lowest. Despite the larger number of tree species at Patle, the number of individual trees was lower than at Fakchamara or Sindhuwa. Total number of trees was highest in Fakchamara and lowest in Fikkal. Three-quarters or more of the total tree fodder was cultivated on bari land, over 95% at two sites, and the rest was obtained from forest and wastelands (Table 2.21).

Table 2.21. Distribution of trees in farmland at each study site

Site	Tree species (n)	Total no of trees	*Bari* land (%)
Sindhuwa	13	697	74.7
Fikkal	14	117	99.1
Patle	23	531	96.6
Mamling	21	419	85.2
Fakchamara	17	1454	83.4

The numbers of trees of each species maintained at each study site is presented in Appendices 3a and 3b. Locally farmers refer to bamboos and *Thysanolaena spp.* as trees and so these are included as tree fodder for present purposes. Of the total 34 tree species possessed by farmers on their cultivable farmlands, *bans (Bambusa nutans)*, *amliso* (*Thysanolaena maxima*), *dudhilo* (*Ficus nerrifolia* var *nemoralis*) and *nebharo* (*Ficus auriculata*) were the most common fodder species available at all study sites (Table 2.22).

Table 2.22. Ten most common fodder trees at each of the study sites, as a percentage of the total trees at the site.

Sindhuwa		Patle		Fikkal		Mamling		Fakchamara		Overall sites	
Tree spp	%	Tree spp	%	Tree spp	%	Tree spp	%	Tree spp	%	Tree spp	%
Dudhilo	28.3	*Bans*	37.3	*Dudhilo*	25.6	*Dudhilo*	21.0	*Dudhilo*	23.0	*Dudhilo*	20.8
Painyu	23.5	*K'khanyu*	10.0	*K'khanyu*	17.1	*Bans*	9.5	*Chamlayo*	21.1	*Painyu*	13.5
Nebharo	16.4	*Rato siris*	9.4	*Nebharo*	13.7	*R'khanyu*	8.8	*Painyu*	14.8	*Chamlayo*	10.1
Gogun	15.6	*Tanki*	7.9	*Amliso*	13.7	*Tanki*	6.9	*Rato siris*	9.9	*Bans*	8.2
Ghurbish	7.3	*Painyu*	5.6	*Gogun*	9.4	*Jhingani*	6.7	*Kutmiro*	9.2	*Ratosiris*	6.7
Bilaune	3.9	*Kutmiro*	5.6	*Bans*	7.7	*Timbur*	6.2	*B'pati*	7.6	*Nebharo*	5.6
B'pati	1.0	*Dudhilo*	3.9	*Painyu*	3.4	*Amliso*	5.5	*K'khanyu*	4.5	*Kutmiro*	5.4
Amliso	0.9	*Chamlayo*	3.6	*Chuletro*	1.7	*Rato siris*	5.0	*Kimbu*	2.5	*K'khanyu*	4.7
Bans	0.7	*Koiralo*	3.4	*Bar*	1.7	*Painyu*	4.8	*Nebharo*	1.8	*Gogun*	4.7
Thotne	0.7	*Ghotli*	3.0	*Bilaune*	1.7	*Chuletro*	4.3	*Tanki*	1.2	*B'pati*	3.8

Note: K'khanyu = Khasre khanyu, B'pati = Bhimsenpati, R'khanyu= Rai khanyu, Bans = represents all bamboo spp.

Other tree species were more location specific, such as *khasre khanyu* (*Ficus semicordata var semicordata*), *gogun* (*Sauruia nepalensis)*, *rato siris* (*Albizia julibrissin)*, *tanki* (*Bauhinia purpurea)* and *patmiro* (*Litsea monopotela)* which were common tree species in Patle, Fakchamara and Mamling whilst not commonly available in Sindhuwa and Fakchamara. *Chamlayo* (*Symplocas robusta*) was a common tree fodder in Patle and Fakchamara but was not found in Fikkal, Mamling and Sindhuwa. *Timur* (*Litsea cubeba*) and *jhingani* (*Eurya acuminata*) were common tree fodders in Mamling but were not present at the other sites. *Amliso* alone contributed 74% of the total supply of tree fodder in Fikkal and 64% in Sindhuwa. In Patle, *bans* contributed about 63% of the total tree fodder supply. Four types of bamboo were encountered in the study: *malbans (Bambusa nutans* var *cupulata)*, *banbans (Dendrocalamus hamiltonii* var *undulate)*, *bhalubans (Bambusa balcooa)*, *choyabans (Dendrocalamus hamiltonii* var *hamiltoni)* and *kalo bans (Dendrocalamus hookeri)*. Bamboo was the only type of fodder that was fed extensively to all categories of animals in all study sites. *Badahar* (*Artocarpus lakoocha*), a highly valued fodder tree species because it is highly nutritious, was only utilized at the Fakchamara and Mamling sites, and although it contributed up to 7% of the total tree fodder supply in Fakchamara, it was not very abundant elsewhere representing only 0.5% of the total available trees across all sites (Appendices 3a and 3b).

2.4.5.2 *Estimated fodder yields*

Estimated tree fodder yields at each site are presented in Table 2.23.The biomass yields were extremely variable at all sites, particularly in Fikkal. There was not much difference in the minima but the maxima varied greatly. Considering the actual tree fodder feeding season, the availability of tree fodder was estimated to range from 0.09 kg dry matter day^{-1} in Sindhuwa to 2.09 kg dry matter day^{-1} in Fikkal (Table 2.23).

Table 2.23: Estimation of the fodder yields per household from tree fodders in each study site

Site	Fodder supply kg^{-1} year^{-1} (range)	AFS kg yr^{-1} (range)[1]	AFS kg day^{-1} (range)[2]	AFS DM kg day^{-1} (range)
Fakchamara	89.4 (3.5-7000)	74 (3.5-5250)	0.35 (0.0-25)	0.12 (0.0-8.7)
Mamling	245 (17.5-5600)	213 (13.1-2800)	1.0 (0.0-13.3)	0.35 (0.0-4.67)
Fikkal	1559 (35-16800)	1256 (35-12600)	5.98 (0.17-60)	2.09 (0.06-21)
Sindhuwa	56.4 (3.5-3500)	53 (3.5-2625)	0.25 (0.0-12.5)	0.09 (0.0-4.38)
Patle	279 (17.5-6160)	204 (17.5-3080)	0.95 (0.0-14.7)	0.33 (0.0-5.13)

The amount of tree fodder (kg) was converted from the local unit '*bhari*'; 1 *bhari* equals approximately 35 kg. [1]Annual AFS, correcting the fodder yield from *amliso* and *malbans* [2]based on actual fodder supply i.e. 210 days representing the seven month long dry season.

2.4.5.3 *Estimation of tree fodder balance*

Based on estimated dry matter requirements, none of the study sites was found to be sufficient for dry matter requirement from tree fodder alone. However, in practice, tree fodders are normally fed with dry roughages. Based on longitudinal monitoring of local practice (Section 2.4.1), about 30% of total dry matter requirement is contributed by tree fodders. Based on this figure, only Fikkal supplied a surplus of tree fodder for feeding during the dry season with an average surplus of less than 1 kg. day $^{-1}$ (Table 2.24). There was a deficit of about 1.5 kg (overall average) in daily dry matter requirement for tree leaf fodder during the dry season (Table 2.24).

Table 2.24. Balance of DM from tree fodders with respect to animal numbers at each study site

Site	Total livestock holding (as large ruminant)	Dry matter intake from tree fodder ($kg^{-1}day^{-1}$ LSU)	Balance of DM from tree fodder* (kg day^{-1} LSU)
Fakchamara	3.5	0.12	-1.28 to -1.88
Mamling	3.7	0.35	-1.11 to -1.7
Fikkal	3.5	2.09	0.09 to 0.69
Sindhuwa	2.3	0.09	-1.3 to -1.9
Patle	3.0	0.33	-1.1 to -1.7
Mean	3.2	0.6	-0.8 to -1.4

*Based on 3.5 to 5.5 kg dry matter requirement per day for animals weighing 200-350 kg live wt (Ranjhan, 1998).

2.5 DISCUSSION

Livestock holdings and animal productivity

According to Anon (2000), the overall population of cattle in Nepal recorded from 1995/96 to 1999/2000 declined whilst the number of buffalo increased. However, in the eastern mid hills, although there was a slight drop in the number of cows in 1998 compared to 1997, there was an increase in the number of cows in 1999. The number of buffalo remained more or less the same during this period. However, the mean livestock numbers of 3.21 LSU per farm (in 2000) are lower than the 4.8 (Gurung *et al.,*1989) reported for the eastern hills about a decade ago, consistent with an overall trend of decreasing livestock numbers. Although factors such as wealth, farm size and ethnic group were reported to have direct impact on the size of animal holdings (Conlin and Falk, 1979, Gatenby *et al.*, 1989a, Thorne *et al.*, 1998), the decrease in forest land and communal grazing areas with increasing human population has a direct effect on animal numbers because of feed shortages induced (Panday, 1990; Pradhan, 1986). Another reason for the decline in livestock population could be farmers' changing attitude towards livestock management as access to open grazing becomes ever more restricted. Some farm households are reducing livestock numbers and introducing larger exotic cross bred cows or buffalo such as in the Sindhuwa and Patle sites. Although reduction of animal numbers is not desired because they are required to sustain crop productivity, farmers in some sites deliberately manipulate livestock numbers to match fodder availability (Section 3.9). The animals are seasonally mated or herd size and composition seasonally adjusted to correspond with the availability of forages.

Accessibility of road and markets has also been found to be associated with the number of animals kept and modification of animal management systems, particularly feeding systems. Kiff *et al.* (2000) have reported an association between animal numbers and accessibility in the central mid hills of Nepal. Other factors such as farm size and ethnicity have also been reported to affect number of animals kept. There is also a relationship between animal population and availability of fodder resources. It appears that the potential for maintaining animal numbers is at least partly determined by the opportunities available at particular locations to grow fodder on farm land or to obtain fodder from common property resources.

In addition to cross-bred cows, at sites with good market access such as Patle and Sindhuwa, farmers are also maintaining local or cross-bred buffalo. According to local people, the milk fat content of cross-bred dairy cows goes below the level that is acceptable to the milk collection centres or Dairy Development Corporation (DDC) (fat content <3.1% and SNF <8.1%), particularly when they are given certain types of forages. In such a situation, farmers often blend buffalo milk with cow's milk to raise the fat content to an acceptable level (the fat content of buffalo milk is normally > 5 %).

The sites with good access to market kept more cows than sites with poor access to market, suggesting that the size of animal holdings is dependent on opportunities open to the farm household. At sites with good market access, farmers are more motivated towards milk production and marketing and hence they keep more cows (mainly cross-bred cows). This practice, however, may be limited to farmers who are relatively rich and can afford to buy exotic animals (Gatenby *et al.*, 1989b). The reasons for keeping livestock amongst farmers with poor access to roads and markets may differ from those of commercially orientated livestock keepers. They may value manure production and draft power rather than milk production and hence keep more oxen. The tendency of farmers in less accessible sites to hold more oxen supports this assumption. In terms of production from milking animals there may be a focus on ghee production rather than increasing milk volume. The higher production of ghee over the three-year period of the study in sites with poor market access (Fakchamara and Mamling) when compared with sites with better market access (Fikkal, Patle and Sindhuwa) is consistent with this. This makes sense, since *ghee* has a longer shelf-life, allowing utilisation for household consumption over a considerable time period or sale in weekly local markets for cash income. Joshi *et al.* (1992) have also reported that the perishable nature of dairy products and the difficulty of transportation in remote areas have prevented the realization of the potential for increased production of milk in the villages of Nepal.

Average milk productivity of the cows in accessible sites, particularly Fikkal and Sindhuwa, was higher than in the less accessible sites. This showed that the farmers in accessible sites get more opportunities and scope to market milk and as a result the farmers employ more inputs and efforts for better return.

Large numbers of sheep and goats in Mamling and Fakchamara that significantly differed from other sites suggested that farmers in the less accessible sites prefer keeping sheep and goats, which may be because they are small and manageable. The holding of larger numbers of sheep and goats in less accessible sites was also related to the holding of marginal land by farm households at these sites. Marginal lands are unproductive and are usually high altitude and sloping, and the farmers leave this land for grasses, mainly thatching grasses. Goats by nature are scavengers and can graze on the sloping lands, which the large ruminants cannot. Another reason may be because of the difference in production objectives between accessible and inaccessible sites. Lack of good markets and remoteness mean that milk production may not be the prime objective. Goats are raised for household consumption and for religious purpose or can be sold as and when cash is required. Market accessible sites are usually dominated by large farmers with the prime objective of raising animals for milk for cash income.

Composition and availability of different fodder types

Tree fodders, forages, fodder grasses and dry roughages formed the main sources of feed for animals. Composition of fodder supplied varied amongst sites, with season and with the type of animals fed. Availability of tree fodders verbally reported by farmers in the study sites was far below the yield estimated by actually visiting sites and inventorying individual trees (average for all sites: 1.3 vs 6.4 tonnes per annum). Verbal information was based on recall and farmers may not remember every fodder species in his/her possession. This also highlighted the importance of repeated measurements for such studies.

Although farmers in Mamling and Sindhuwa had fewer fodder trees on their own land than farmers at other sites, they supplied tree leaves in a quantity similar to the farmers at Fikkal and Patle. This suggests that these farmers have some access to off-farm fodder sources. Interviews revealed that some farmers gather tree leaves from nearby private forests, wastelands or farmlands of others who have a lot of trees but do not wish to collect them because of labour and time constraints.

The number of tree species found to be extensively used for fodder in this study was 34, higher than reported for the Western hills and other hill districts of Nepal. Rana and Amatya (2000) reported 17 different species as most common in the western hills whilst Dhakal (2002) reported 24 (based on a survey in 51 districts). Anon (1990) reported 32 different tree species cultivated by dairy farmers in the whole of the mid hill belt across the country. Gatenby *et al.* (1989a) estimated annual dry matter supply from tree fodder ranging from 50 to 60% for large ruminants in the Koshi hills while 41% was reported by Panday (1982). However, these authors did not mention whether the measurement was for over the whole year or seasonal. Nineteen percent contribution of tree fodder to the annual fodder supply identified in this study is more realistic since measurements were made throughout the year. This figure is slightly higher than the value of 12% reported by Anon (1990) for cattle and buffalo in Nepal. The contribution of tree fodder however rises to about 30% at the height of the dry season, with about 72% of the total annual tree fodder DMI being consumed during this time.

Grasses are an important source of dry matter, contributing about 45% of annual DMI and at some sites contributed throughout the year, although the intake varied depending on availability. Grasses that were derived mainly from nearby riverbanks, private or government forests, community forests and wastelands contributed 29% of the total DMI during the dry season. These grass species are available when soil conditions are moist and farmers collect them from wasteland and forest undergrowth where soil conditions do generally remain moist. Also, there are some common exotic grass species i.e. napier, *narkat* and oat grass, maintained most evidently in Fikkal, that may be available for feeding during the fodder scarcity period of the dry season.

Selection of grass species, including domestication of promising native species such as *udase* (botanical name unknown), *kamle* (*Pilea wightii*), *salimbo* (botanical name unknown), *thotne* (*Ficus hispida*), *kans* (botanical name unknown) and *chiple* (*Eragostis tennella*) may help to alleviate dry season feed deficiency. Grasses were also available from the irrigated *khet* land. However, some farmers do not normally collect grasses from *khet* lands, since considerable manpower is required for collection and transportation because of the relative remoteness of *khet* land from the homestead. This was particularly the case in Fakchamara. Secondly, there are other fodders and forages abundantly available during the wet season close to dwellings.

Green forages during the wet season are adequate for supporting the existing animal population. During the wet season, animals receive adequate nutrition from available fodder resources and in general they remain in a productive condition. However, during the dry season the animals are fed on dry roughage supplemented with tree leaves. As a result of the scarcity of fodder, the productivity of milk drops during the dry season. For example, the daily total collection of milk in one of the dairy co-operatives at Hile (along the Dhankuta-Basantapur highway) is approximately 200 l during the dry season whilst during the monsoon, this goes up to 375 l (Officer in-charge, dairy co-operative, Hile, *pers. Comm.*).

Farmers in the hills grow very few forage crops for dry season feeding, perhaps due to a lack of land for cultivation. Although conservation practices and treatments for crop-residues, tree fodders and forages are available, these are not widely used during the dry season. As a result, most of the time animals are fed on low quality dry roughage. Farms at sites possessing more *khet* land generally had more dry roughages (mainly rice straw), as in Fakchamara. On the other hand, Fikkal farmers having more forest and wasteland had better access to tree fodder resources. The accessibility of more tree fodder resources was reflected in better nutrition and productivity of animals at the Fikkal site.

Dry roughages form an important source of energy during the dry season when other sources of fodder are unavailable. Since dry roughages have low digestibility and low availability of nutrients (Greenhalgh, 1980), efforts have been made to improve their feeding value generally (Haque, *et al.*, 1983; Jayasuria, 1985; Wanapat, 1985) and specifically in Nepal (Chemjong *et al.*, 1990; Khanal and Rana, 2001, Dhaubhadel and Tiwari, 1991). Adoption of these technologies at farm level in Nepal has been low for a variety of reasons (Shrestha, 1992) such as unavailability of input supply, labour costs and a general lack of interest.

A variety of ingredients are used to make the local concentrate, *khole*, that is fed to lactating animals. The ingredients, however, vary with season and some are quite specific to individual farms. Farmers in Fikkal and Sindhuwa, who own large crossbred cows, generally provided more *khole* for their animals than farmers at other sites. Intake of *khole* may be related to the accessibility of roads and markets. This was reflected in that Fikkal, Patle and Sindhuwa farmers tending to supply their animals with more cereal by-products (maize flour and rice or wheat bran) than those at less accessible sites (Fakchamara and Mamling). Another factor affecting composition of *khole* ingredients relates to the activities of individual farms. For example, farmers of Sindhuwa and Patle producing commercial vegetables tended to use waste vegetables, that were discarded and unfit for human consumption, in their animal feed. Few farmers in Fikkal used vegetable waste to make *khole* but almost all of them used mustard cake. while only a few farmers in Fakchamara and Mamling and none in Patle and Sindhuwa used mustard cake. Fikkal farmers were feeding mustard cake at higher amounts (0.5 $kg.day^{-1}$) than reported previously by Wattiaux (1995). Since oil seed cakes are good in terms of protein availability (heat processing perhaps reduces degradability in the rumen) in the duodenum, it may be worth trying to promote incorporation of oil seed cakes more widely for ruminant animals in Nepal. Oil seed cakes that are readily available in villages may contain more oil compared to the commercial oil seed residues but availability may be an issue at more remote sites. Lactating animals were given more, higher quality fodder than the oxen, including greater use of *khole*. However, the supply of *khole* for oxen depended on the amount of work they performed and was related to the cropping calendar. This suggests a direct correspondence between the use of *khole* and income generation. This was also observed in a difference in the use of roughage to concentrate ratio. Farms with access to roads and the fresh milk trade were generally found to have a low ratio of roughage to concentrate (5:1) whilst farms in Mamling and Fakchamara with poor access to roads and the fresh milk trade had much higher ratios (up to 16:1). This suggests that the use of *khole* is dependent on the accessibility of its ingredients to a farm household and perhaps to any economic returns a farmer expects from his or her animals. Although farmers tended to increase supply of *khole* during the dry season particularly to lactating animals, the difference was only significant for calves. The farmers interviewed expressed that rapid growth and increased productivity of animals could fetch more income (Section 3.9.1.4) from the quick sale of animals. In further interviews with the farmers, it was found that local male calves (for use as draught power in less accessible sites) and cross-bred female calves (for use of milk production in accessible sites) are quickly sold.

Supply of nutrients from different feed resources

Tree fodders are supplied during the dry season to improve the nutrition of animals (Rana and Amatya, 2000). Some tree species were also used during the wet season together with grasses. However, the major contribution from tree fodder could be seen from the increased intake of tree fodder (average intake of all animals) from 2-3 kg (average intake of all animals) in November/December to 2.5 to 3.5 kg in April/May. The intensive use of tree fodder can also be judged by its increased intake by animals. Beside 24% of protein, the importance of tree fodders as the principal source of energy is illustrated by its 40% contribution to the energy supply during the dry season. Various authors have stressed the importance of trees as a nutrient supplement during the dry season (Panday, 1982; Rana and Amatya, 2000; Poudel and Rasali, 1996). They are often used as a supplement to dry roughage based diets to improve nutrition of ruminant animals. Some farmers, notably in Patle and Fikkal, utilised tree fodder (particularly bamboo species) throughout the year. It appears from the yield data of individual trees in each site, that in Fakchamara, Sindhuwa and Mamling farmers did not possess enough tree leaves to supplement dry roughages. With the current tree fodder resources, if the animals are to be fed as per recommendations (Ranjhan, 1998), with 60% dry roughage, all the farm sites except for Sindhuwa had sufficient tree fodder, provided wastages were minimized. Kshatri (2000) reported that 2-4% of tree fodders are wasted if they are offered as sole feed whilst Oli (1988) estimated a loss of 25%, if the fodder is fed on the ground. Also, large animals generally rejected branches of trees that were larger than 26 mm circumference (Oli, 1988).

The 28% contribution of dry roughages to the total energy intake during the dry season shows that they are also an important source of energy, although availability can be low due to presence of lignin (Greenhalgh, 1980). As the dry roughages are low in DCP, there may be a significant synergy to improve the feed utilization when dry roughages are combined with tree fodders or grasses that have high availability of protein (Khanal and Subba, 2000). Various authors in Nepal (Khanal and Rana, 2001; Chemjong, 1989; Chemjong *et al.*, 1990, Dhaubhadel, 1992) and abroad (Dahiya *et al.*, 1998; Haque *et al.*, 1983; Jayasuria, 1983; Wanapat, 1985) have suggested improving utilization of dry roughages, which are of low quality through various physico-chemical treatment methods.

As the lower part of rice straw is the main contaminating source of liver fluke, causing production losses of the animals, recently Mahato (2000) suggested feeding only the top portion of the straw before March and the bottom portion after mid April. This would prevent animals from being infected with liver fluke and thus minimize production losses as a result of this. Also it would mean a reduction in feed required by animals due to the absence of liver fluke. Rice straw would then be utilised much more efficiently.

Unlike commercial concentrate, which is high in energy, *khole,* the local concentrate, gives only 21% of the total energy intake during the dry season. However, the contribution of *khole* to the nutrition of animals in the form of protein is large, contributing about 52% of the total protein intake of the dry season. Additionally, *khole* may have a role in supplying minerals, particularly sodium, since farmers normally supplement common salt in the preparation of *khole*. Farm households, particularly those who are in less accessible areas, may benefit from improving the quality and quantity of *khole* that they feed. Farm households who are not supplementing mustard seed cakes as a protein source need to consider using it. However, attention needs to be given to feeding mustard seed cakes, since substances present in it may cause deleterious effects to the animals if fed uncooked (Cheeke, 1985).

Grass is an important source of nutrients in farm households holding more *bari* land, such as Fakchamara and Sindhuwa. On average about 19% of energy and 34% of DCP was contributed to the total annual intake of these nutrients from grasses. About 11% contribution of energy and 23% of protein in the dry season showed that grass is also an important source of nutrition. Conservation of seasonal grasses in the form of hay or silage is not normally practised in the hills, apart from the preparation of hay by some farmers in the snow covered mountain areas in the north of the country (Khanal *et al.*, 1999). Preparation of hay is less cost-effective to the farmers because of lack of land for cultivation of grasses for hay and the labour costs that overlap with the rice cultivation season. Some farmers in the upper mid hills near forest areas and in areas accessible to marginal lands let grasses stand which are cut after they are over mature for the purpose of thatching and winter feeding. As the quality of the dry grass is poor, a farmer's aim in feeding this would be to fill the animals at the time when food supply is short.

Adequacy of diets and additional feed requirements

As expected, intake rate was lowest in March/April when availability of grasses is low. Various strategies adopted by local people to cope with fodder shortage and find alternative feeds during the dry season will be been explained in Section 3.9. The overall intake rate (kg $head^{-1} \cdot day^{-1}$) was found to be higher than the expected feed intake and the recommended dry matter intake data for Indian animals (Ranjhan, 1998). The intake rate of buffalo agreed fairly well with the recently surveyed feed intake rates by Hendy *et al.* (2000). However, the intake of cows and oxen was slightly higher than the intake rates reported by Hendy *et al.* (2000) and than the higher dry matter intake recommended for Indian animals for production (Ranjhan, 1998). It is closer to the intake reported by Joshi *et al.* (1992) for crossbred and local cattle in the western hills of Nepal, if 8 to 10 hrs grazing were also considered. Poudel and Rasali (1996) have also obtained an intake of about 11 kg of dry matter when 40 kg of *badahar* leaves were offered to lactating buffalo in the western hills of Nepal. In the eastern hills of Nepal, in an on-farm experiment on lactating buffalo, Shrestha and Pakhrin (1989) reported intake of some tree fodders that ranged from 6 to 10 kg per day. The animals also received 10 kg of rice straw and 3.4 kg of *khole*. Such high intake rates could reflect analytical error relating to recording of the uneaten portion. Monitored animals or their neighbours might have displaced the uneaten portion by movement or trampling, or other members of the household might have cleared the uneaten portion in the absence of the household head. In the absence of any uneaten fodder, it was assumed that everything offered was eaten. In addition to this, the use of a 4.0 kg spring balance (accuracy ±100g) to weigh feed samples might have further reduced accuracy of recordings. However, the farmers who participated in the trial accepted that the observed level of dry matter intake in animals was realistic. Many of them said 'the intake of ruminants is high, they always keep on eating, and appetite of ruminants is very difficult to satisfy'.

The following discussion assumes that the animals actually consumed this amount of dry matter. Cows and buffalo in accessible sites (Patle, Sindhuwa and Fikkal) received higher levels of protein and energy compared to the less accessible sites (Mamling and Fakchamara). Although there was limitation in farm fodder resources (except for seasonal grasses) for the farmers in Sindhuwa (accessible to road and market), both cows and buffalo were within the normal requirements of energy. This was reflected in the apparently healthy body conditions of animals. This showed that the farmers used other feed resources for feeding to the animals. Meeting individuals during the repeated visits confirmed that the households purchase crop residues such as rice straw, rice bran and maize grain during glut season for feeding for the whole year. In addition, the higher level of protein and energy in market accessible sites could be because farm households in accessible areas are more commercially oriented as they expect more economic return from the amount they spend for protein and energy foods. Mustard cakes are not readily available in less accessible sites and the practice of supplementing this in the ration has yet to be established. Likewise, cereal products such as rice bran and maize flour are also seasonally dependent in less accessible sites whereas these are readily available in accessible sites.

The apparently healthy cross-bred cows yielding a satisfactory level of milk production at market accessible sites justifies the conclusion that the animals have a satisfactory level of nutrition, although the DCP they received was only at maintenance level when compared with the Indian standard (Ranjhan, 1998). Comparatively low productivity of the cows at less market accessible sites may be due to them receiving a lower level of energy and protein compared to the accessible sites. Borderline levels of energy from the normal requirement and deficiency of protein in the diet could cause severe deficiency, affecting their productivity as a result of seasonal fluctuation in these nutrients with the availability of feeds. Karki (1984), when analysing livestock and feed resources in the mid hills, concluded that there is enough protein to sustain 10 kg of milk production (with 5% fat) but there is shortage of energy. His study was based on secondary information sources: the result of the current study that there is deficiency of both protein and energy in the diet of animals in the hills appears more reasonable. This was also supported by the positive response on the milk yield in a group of lactating buffalo fed on urea molasses liquor at Patle (Poudel, *pers. Comm.*)[8].

Oxen received only maintenance levels of energy and their protein intake was also at subnormal level in all the study sites. Oxen become lower priority to a farmer in the presence of lactating cows or buffalo except at the times they are working. Therefore, oxen are subject to severe protein and energy deficiency particularly during the dry season, where they spend more energy finding food than they obtain from it (Khanal *et al.,* 1999).

The energy intake of calves at all sites was within the normal requirements for growth and maintenance except in Sindhuwa and Fakchamara where the calves received energy at maintenance level only. However, the protein they were receiving was not sufficient to support growth and they were at severe threat of protein deficiency. The protein and energy status of calves, irrespective of accessibility to road and markets, may be related to the breed and their value to a farm household. Changes in farmers' feeding strategies with respect to the productivity of animals will be discussed in Chapter 3. Local male calves are generally more valued than the cross-bred male calves by farmers, as they can be used for draught power and are quickly sold (Gatenby *et al.,* 1989a). Cross-bred

[8] Mr T.P. Poudel is technical officer at Agricultural Research Station, Pakhribas

female calves are highly valued for milk production and sell more quickly than the local female calves. Relatively high intakes of protein and energy for calves at Patle and Fikkal suggest that the farmers in these two sites give more attention to the nutrition of young or growing animals. Farmers at these sites are involved in the animal trade. Purchase of young animals and disposing of old and unproductive animals is one of the strategies adopted by farmers in their feed planning during the dry season (Section 3.9).

Relatively low intake of DCP for oxen and higher intake for cows and buffalo suggests that farmers in the eastern hills see oxen as of lower priority than either cows or buffalo. The low priority given to oxen is also illustrated by the fact that farmers tend to feed them higher proportions of dry roughages with only occasional small quantities of *khole* (preferably given after work). The supply of low quality fodder to fill oxen and unproductive animals whilst good quality fodder is supplied to lactating animals is also a prevalent practice in the western middle hills of Nepal (Kayastha *et al.,* 1998).

Intake of digestible crude protein was not enough for normal production in all categories of animals in all study sites, necessitating increase in the supply of protein rich feeds. Attention needs to be paid to increase in the supply of protein rich feeds. Oilseed cakes are costly and are not easily available to all categories of farmers, particularly in less accessible areas. As the effort to increase utilisation of crop residues through urea treatment was successful under experimental conditions only (Shrestha, 1992), an alternative means for achieving increased supply of protein could be through additional supply of tree fodders rich in protein content (Subba, 1999) and legume forages (Singh, 2000). Recently a system of feeding called "complete feeding" has been introduced in India (Sengar and Naik, 1996). This involves better utilization of agricultural and industrial by-products to supply other nutrients to meet the nutritional requirements of livestock for different physiological functions. However, such an alternative feeding strategy is still at an experimental stage and appears to be suitable for large farmers only in India. Efforts to conserve surplus forages of the monsoon season have been suggested for use in Nepal by Singh (2000) and conservation of tree leaves in the hills in India by Balaraman (1996) but such practices have yet to be established in Nepal.

Intake of protein as DCP was sub-optimal and that of energy was within the normal requirement for maintenance and production for cows, buffalo and calves except for oxen which are in maintenance level when compared with the recommended daily requirements of protein (DCP) and energy (ME) requirement for Indian breeds of animals (Ranjhan, 1998). Estimates of ME and DCP in this study were based on *in-vitro* rather than *in-vivo* measurements and may overestimate energy and protein levels supplied by livestock diets.

2.6 Conclusions

Overall livestock numbers in the eastern hill are decreasing. Some farm households are reducing numbers of local livestock and introducing larger exotic cross-bred animals, particularly in areas accessible by road. Market accessible sites were more motivated towards milk production and marketing and kept more cross-bred cows whilst less accessible sites maintained larger numbers of sheep and goats than the accessible sites. Reasons for keeping livestock amongst the farmers in less accessible sites was for manure, draught power and ghee production.

Tree fodders, grasses, dry roughages and *khole* were the major fodder types in the eastern mid hills of Nepal. The contribution of these fodder types differed with season, with the proportions of tree fodder and dry roughages particularly high during the dry season. Tree fodders formed an important green fodder supplement during the dry season, contributing about 30% of the total DMI at this time. Tree fodder was an important source of protein and energy, contributing about 33% of energy and 16% of DCP on an annual basis. A total of thirty-four tree species were commonly cultivated and maintained by farmers on their farmland, with fifteen species common in all study sites. The biomass yields of tree fodders were extremely variable at all sites. With about 30% of the total dry matter requirement of an animal contributed by tree fodders, the supply of tree fodder appeared to be sufficient to meet the dry matter requirements for the current livestock population in Fikkal but planting more fodder trees may be appropriate at the other sites, with a negative fodder balance. Private and government agencies with the objective of improving animal production should take initiatives to promote tree fodders to supplement dry season diets.

Thirty-three different local grass varieties were offered to the animals during the wet season (appendix 2.5). Even in the dry season, they formed an important source of dry matter, energy and protein. Dry roughages were utilised over the whole year, but were a particularly important source of dry matter and energy during the dry season. Tree fodders were supplemented with rice straw and other crop residues in the dry season whilst rice straw was fed with grasses in the wet season to obtain a desirable mixture and improve feed utilisation. Protein in tree fodders complements energy in dry roughages to improve the protein and energy nutrition of animals on dry season diets.

Khole was an important source of energy and protein, contributing about 21% of energy and 52% of DCP on an annual basis. Composition and quantity of *khole* varied from place to place depending on farm practices, season and accessibility to roads and markets. Khole at accessible sites (Patle, Sindhuwa and Fikkal) with exotic breeds, generally included a higher quantity of cereal and oilseed by-products than that in less accessible sites. *Khole* was offered both in dry and wet seasons with intake slightly higher in the dry season than in the wet season. The farmers often supplied *khole* according to animal productivity. Oxen were generally fed on low quality fodder as they were regarded as unproductive and received *khole* only after seasonal draught work, whilst lactating animals and calves were fed with khole and other high quality fodders more regularly throughout the year.

The overall dry matter intakes reported in the present study may have included some material that was wasted rather than ingested and were higher than intakes reported for similar breeds of animals in India. The intake rate was higher in the wet season than in the dry season. Although cows and buffalo in accessible sites (Patle, Sindhuwa and Fikkal) in general received higher levels of DCP than those at the less accessible sites (Mamling and Fakchamara), the intake was just at the maintenance level whilst the DCP intake of both calves and oxen was lower than the Indian standard and animals were at severe threat of DCP deficiency, suggesting that farmers could obtain a return from increasing the supply of protein rich feeds. The energy intake of cows, buffalo and calves in accessible sites were within the recommended daily requirements of energy for maintenance, growth and production of Indian breeds of animals whilst less accessible sites were at the borderline of normal requirements. However, oxen in all study sites were only at maintenance levels of energy requirement. These results imply that there is a need for increased allocations of high quality feeds, particularly protein rich feeds, in general for all categories of animals and energy rich feeds to oxen in particular. To ensure adequacy of protein and energy, farmers mainly in less accessible sites, should routinely supply oilseed cakes and milled products where possible. As the introduction of exotic germplasm into the indigenous pool in accessible sites is increasing every day, farmers at these sites also require understanding of the general and specific nutritional requirements for efficient production of milk from these highly productive animals.

CHAPTER 3

LOCAL KNOWLEDGE ON UTILISATION AND MANAGEMENT OF TREE FODDER

Over view

This chapter reports on the documentation of local knowledge about the use and management of tree fodders in the eastern mid hills and local strategies to cope with dry season fodder shortages. A more comprehensive understanding of attributes of fodders that farmers identify and use to evaluate fodder quality are revealed than has been previously understood. These are then used as a basis for investigation of the scientific bases of farmers' perceptions in later chapters.

3.1 Introduction

The farming system in the middle hills of Nepal is complex with most farmers depending on crops, livestock and forests for their livelihood (Thapa *et al.*, 1997). Farmers cultivating land also raise livestock that heavily influence nutrient cycles (Thorne and Tanner, 2002). Manure from animals is vital for the maintenance of soil fertility, while livestock depend on fodder from forest or farm trees, particularly in the winter. Mahat (1987) reported that these are interdependent components with changes in any one having effects on the others.

Rural people, dependent upon the environment for their livelihood have often been found to have an intimate knowledge of many aspects of their surroundings as affected by their daily lives, which they have accumulated and conserved over many generations (McClure, 1989). This is often referred to as indigenous knowledge, the knowledge that the people in a community have developed over time but farmers are also active observers of the environment and often experiment so that their local knowledge base is contemporary and dynamic (Chambers, 1992).

Since Nepalese farmers have substantial local knowledge and management capability relating to animals, trees and forests (Thapa *et al.*, 1997), any attempts by government or other agencies to intervene in natural resource management are likely to be more effective if they do so by starting with an appreciation of what is already known by the farmers. Local knowledge has often been neglected in the past, and this may have contributed to the failure of many development efforts because they may not have been appropriate to the interests of the farmers (Warren and Cashman, 1988; Fujisaka, 1994; Schoonmaker Freudenberger, 1994). A recent questionnaire survey by Dixit *et al.*, (2000) revealed that the majority of livestock farmers interviewed in some villages in Haryana, India preferred local practices than to follow official recommendations, since the farmers felt that local practices were sustainable, as they aimed at round the year maintenance of animals well within the feed resources that were available.

Research problems and priorities are identified by the needs and opportunities of the farm family rather than by the professional preferences of the scientist (Chambers, 1987). Ortiz (1999) expressed his concern that scientific and local knowledge could interact within the dynamics of the knowledge evaluation within the farming community; as a result there may be conflict and competition between them. Both local and scientific knowledge have strengths and weaknesses (DeWalt, 1994 and Antweiler, 1998). Scoones and Thompson (1994) and Antweiler (1998) have emphasized the need for merging the strengths, knowledges and capabilities of both farmers and agricultural scientists to derive productive outputs.

Walker *et al.* (1997), in a pilot study, suggested that institutional gains were possible from using local knowledge as a basis for planning new research and extension at a frontline agricultural research centre such as Agricultural Research Station, Pakhribas (ARS-P). The development professionals could blend local knowledge with science to produce sustainable solutions to problems of a community, specific to local circumstances.

As was documented in the previous chapter, tree fodder is an important source of animal nutrition in the hills of Nepal, often providing the only green fodder during critical times of the year. It has already been demonstrated that Nepalese farmers possess a sophisticated indigenous knowledge system describing the nutritive value of tree fodders. Thapa *et al.* (1997) reported two local criteria for describing the nutritive value of tree fodder used by farmers in Solma VDC in the eastern hills of Nepal, *posilopan* (literally meaning nutritiousness) and *obhanopan* (literally, dryness and warmness, but also referring to how fodders are eaten and their digestibility). Farmers across the eastern mid-hills of Nepal have been found to share these descriptors for tree fodder value (Joshi, 1997) and to apply them consistently and independently to fodder from different tree species (Walker *et al.*, 1999). Early efforts made to compare farmers' overall preferences for fodder with chemical measures had revealed no scientific explanations (Subba *et al.*, 1992) but comparison of farmers' ranking of different fodders in terms of *posilopan* and *obhanopan* with *in vitro* chemical analyses, suggested that these descriptors may relate to protein supply and overall dry matter digestibility respectively (Thorne *et al.*, 1999). These authors found that local knowledge was comparable with scientific knowledge but also reported marked contrasts in how scientists and farmers interpreted knowledge associated with different value judgements. Farmers, for example, recognised and valued the long duration of appetite satisfaction associated with less digestible fodders, while scientists assumed that high digestibility was preferable (Thorne *et al.*, 1999). These findings suggested the importance of an integrated approach to intervention planning related to livestock feeding based on combinations of local and biological information.

This study attempts to investigate local knowledge about tree fodder in Nepal in more detail and to relate it to scientifically conducted feeding trials in later chapters. The specific focus is the feeding and management systems of ruminants, especially in the dry season, when the local people have problems in providing adequate diets for their animals, as documented in Chapter 2. It aims to provide a picture of how the local farmers manage animals and local feed resources and examines the local strategies to cope with fodder shortages in the middle hills particularly during the critical dry period.

3.2 MATERIALS AND METHODS

3.2.1 General methodology

The general methodology builds on the use of knowledge-based systems techniques to acquire local knowledge and use it in planning research and extension (Walker *et al.*, 1995). Knowledge bases are dynamic, because they can be updated and improved with more knowledge as it is encountered. This study adds further knowledge about tree fodder to that previously collected by Thapa *et al.* (1997). This includes more information on fodder trees, and particularly on strategies to cope with dry season fodder shortages. For this purpose, various forms of interview were conducted with over 200 farmers in eight villages over the course of the study. Initially 66 individual farmers, identified as knowledgeable, were purposively selected from six VDCs in the eastern hills, including Solma VDC where Thapa *et al.*'s (1997) study was conducted. The agroecological knowledge toolkit (AKT) methodology and software was used to document and analyse information elicited from farmers in semi-structured interviews by creating and then refining a computerised knowledge base. Conflicts and uncertainties were then resolved in group interviews with 93 farmers at eight sites, many of whom had contributed knowledge initially. Key topics within the knowledge base were included in a verification survey with farmers not involved in developing the initial knowledge base to explore knowledge distribution. This verification survey involved group interviews with 66 farmers at six sites to rank 15 common types of fodder for key attributes, and two questionnaires administered to a stratified random samples of informants. The first of these covered questions on feeding and fodder management administered to 66 farmers and the second was about strategies for coping with dry season fodder shortages administered to 78 individual farmers, some of whom had also been informants for the first questionnaire. The verification survey itself identified a new area of knowledge requiring further investigation concerning the impact of weather conditions on fodder value and palatability that was explored in group interviews with a further 20 farmers all at one site. Each of these stages is explained in more detail below.

3.2.1.1 *Selection of sites and informants*

Knowledge acquisition was conducted in Fakchamara, Mamling, Fikkal, Sindhuwa, Patle and Solma Village Development Committees (VDCs) in the mid hills. Fikkal (in Ilam district), Patle and Sindhuwa (in Dhankuta) district have good access to markets. The animals are mainly maintained using a stall-feeding system. Livestock keeping, particularly dairy cattle and buffalo are, profitable enterprises that are expanding in these VDCs. On the other hand, Fakchamara, Mamling and Solma are remote VDCs with predominantly subsistence agriculture. They have relatively poor access to roads and markets. Animals in these sites are maintained mainly using grazing systems. Background information for Fakchamara, Mamling, Fikkal, Patle and Sindhuwa are given in detail in Section 2.2.1. These villages with different accessibility were selected to obtain farmers' assessments of nutritive value from villages with different market and road access.

Prior to the initiation of the study, one assistant in each VDC was hired to assist acquisition of accurate information from farmers. The assistants were also involved in the activities described in Chapter 2. It was reported elsewhere that women are often hesitant to speak in presence of men (Gurung, 2001), so the researcher was assisted by women enumerators to facilitate interviewing women farmers. This brought openness among women to express their views among themselves and in front of the female interviewer. Realizing the importance of giving orientation to the enumerators (Ellen, 1993), they were given training about interview procedures and objectives of the project. The interviews were conducted in a place and on a date preferred by the farmer being interviewed.

A total of 66 knowledgeable farmers were purposively selected and were interviewed individually during the knowledge acquisition process. Interviewees were chosen as follows.

1. Two local people already cooperating in longitudinal monitoring (Section 2.2.4) were asked to name seven male and seven female farmers who knew a lot about the topics in question.

2. This was done in transect walks through the villages with the two local people following zigzag routes in the mid hill altitude range, during which the local informants pointed out farmsteads where knowledgeable farmers resided.

3. These farmsteads, at locations scattered through the village and at considerable distances from one another, identified during the transect walks, were then visited for discussion. If the person was found absent, the next household with an identified knowledgeable farmer was selected.

4. Informal discussions were held with the farmers reported to be knowledgeable. Those able and willing to participate in the study were selected for the actual interview process.

5. Some farmers who were participating in the repeated survey measurements (Section 2.2.2) and feeding experiments (Chapter 4) also became interviewees. Because of frequent interaction with the local farmers, the researcher had established good rapport within the community, and a few non-participating farmers who demonstrated that they were knowledgeable and keen also volunteered their knowledge during interviews.

3.2.1.2 Individual and group interviews to acquire knowledge

Knowledge acquisition was initiated in the year 2000 and continued until 2001. The acquisition of knowledge from local farmers was conducted during the dry period, starting from October/November until March/April each year.

The acquisition of knowledge was carried out following knowledge-based systems methods developed and tested in Nepal (Sinclair and Walker, 1998; Walker and Sinclair, 1998). The knowledge acquired from farmers was represented as unitary statements, each containing a single item of information, with associated definitions and taxonomies of terms used in them, as per the WinAKT5 methodology (Dixon *et al.*, 2001). Details of the interview process, that is, the source person's name, their gender and the date and location of the interview were also stored and associated with each statement. The knowledge acquisition involved two tightly coupled stages: 1) elicitation, which included individual interviews followed by verification of knowledge in group interviews and then 2) knowledge representation that involved creation of a knowledge base on computer and its assessment and refinement. The knowledge acquisition often involved repeated discussions individually as well as in groups. Repeated discussions were essential to ratify some of the observations and claims of the respondents.

Appointments were made with identified respondents and they were informed how much of their time the study would take. Based on this, dates and time for interviews were fixed at least a day in advance. When the farmers were approached to be involved, and before each interview, the farmers were made clear as to how the results would be used and how this could benefit an individual or a village.

The individual interview was conducted any suitable time, according to the comfort of the interviewee. Often, questions were asked at the time when the farmers were having a rest after their usual farm or household work. Questions were left for another day if the interview took longer than one hour. Non-leading questions were asked within semi-structured interviews with support from two trained enumerators. The interview was kept open ended so that the farmer could discuss and express their views freely but enumerators guided the discussion where appropriate with a checklist of issues to be discussed. The responses of each interviewee farmer were recorded using a dictaphone and notes were taken. The interview was later played back and cross-checked with the written notes. Follow-up interviews were made for clarification. The information thus collected was then represented using WinAKT5 as a set of unitary statements in a formal grammar with associated definitions and taxonomies of terms.

The interviews involved discussions with farmers about their knowledge on feeding and management of ruminant animals and tree fodders during the dry season. The interviews were also directed at understanding the strategies that farmers used to cope with the shortages of tree fodder during this critical period. During the discussions, some questions were prompted by direct observation of farmer practice. They were asked about the feeding values of tree fodders they used and the reasons for their preferences. The participating farmers also led the researcher to farm premises to demonstrate available farmland fodder resources and to explain feeding and animal management systems that they were practicing. Some interesting points coming from discussions with people met on transect walks were also noted.

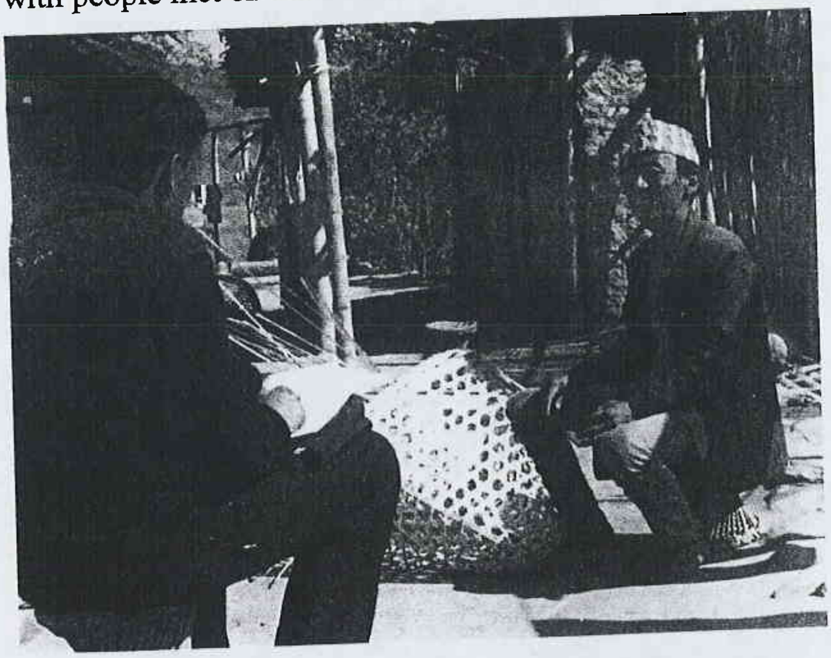

Plate 3.1 Interview with a farmer in Fakchamara (above).

Plate 3.2 A farmer differentiating toxic (white) and non-toxic fodder plants of the same species (*Lindera* spp) by leaf colour (below).

Group interviews were conducted at eight locations for verification of the knowledge base largely with the key informants who had contributed to it. The interviews were conducted at the five initial sites as well as three convenient sites close to ARS-

Pakhribas (Barbote, Basantapur and Chungbang). The knowledge derived from individual farmers was discussed for further clarification until a general consensus was achieved in each group. Each group comprised from eight to 20 farmers with approximately equal numbers of men and women (Table 3.1).

Table 3.1 Numbers of farmers participating in group verification interviews at each site

Site	Gender	
	Male	Female
Patle	8	7
Sindhuwa	7	5
Mamling	10	10
Fikkal	13	5
Fakchamara	5	5
Solma	6	5
Barbote	6	6
Chungbang	5	3
Basantapur	5	5

*3.2.1.3 **Ranking Of Common Tree Fodders***

Group interviews were conducted to rank tree fodders involving six to eight knowledgeable male and female respondents. The participants were randomly selected from the list of knowledgeable farmers previously complied (Section 3.2.1.1.1). Knowledgeable farmers in Solma were representative of the farmers from ward no 1 only. Thapa (1994) and Joshi (1997) carried out extensive studies on local knowledge in Solma. Solma was considered again here to compare whether the knowledge held by farmers in Solma was representative of other study sites.

The venue for the group interview was usually a house of one of the participants or a school within the village usually at a central location for all informants. The number of participants interviewed in the group meeting at each study site is shown in Table 3.2.

Table 3.2. Numbers of farmers participating in group ranking interviews by site and gender

Site	Gender	
	Male	Female
Patle	7	7
Sindhuwa	7	7
Mamling	7	7
Fikkal	7	8
Fakchamara	8	6
Solma	7	8

The tree species identified as most common across the study sites (Section 2.4.5.1) were used for ranking and group interviews (Table 3.3). Although bamboos and *amliso* belong to the graminae family they have been counted as fodder trees here because they are subjected to lopping and considered as tree fodder by farmers.

Table 3.3 Common fodder trees cultivated in the eastern middle hills used for ranking in group interviews.

Local name	Botanical name
Malbans	*Bamboosa nutans*
Badahar	*Artocarpus lakoocha*
Amliso	*Thysanolaena maxima*
Khasre khanyu	*Ficus semicordata var semicordata*
Nebharo	*Ficus auriculata*
Patmiro	*Litsea monopotela*
Rai khanyu	*Ficus semicordata var Montana*
Chuletro	*Brassiopsis hainla*
Dudhilo	*Ficus nerrifolia* var *nemoralis*
Tanki	*Bauhinia purpurea*
Kabro	*Ficus lacor*
Rato siris	*Albizia julibrissin*
Painyu	*Prunus cerasoides*
Gogun	*Sauruia nepalensis*
Bhimsenpati	*Brideja asiatica*

The interviews were conducted separately for male and female farmers on separate dates and at mutually agreed venues. Ranking of the tree species was carried out following participatory rural appraisal (PRA) techniques (Vabi, 1996). Farmers were asked to rank the 15 fodder types in terms of their *obhanopan*, *posilopan* and *adilopan* status. Leaves from each of the 15 fodder trees were placed on the ground and informants were asked to identify the most *obhano* fodder species. They were then asked to identify the most *obhano* fodder of the remaining 14 tree species. Likewise, they were asked to identify the next most *obhano* fodder and place it in rank order related to the first two, and so on until all the leaves were placed in rank order. In order to avoid inconsistencies, the ranking was repeated from least *obhano* or most *chiso*. The same procedure was then employed to rank for *posilopan* and *adilopan* status. The interviewers facilitated the discussion and the ranking. Any controversies in the final ranking were discussed and re-ranked until a general consensus was achieved. This allowed farmers to compare and discuss their selection. During the ranking exercise farmers' reasons for their choice of rank order were discussed and key points were noted. Cigarettes or tea and biscuit were served to the participants when the group meeting was in progress. Children accompanying parents were given sweets. These refreshments made the meeting lively and made people more responsive.

3.2.1.4 Questionnaire survey

A structured questionnaire survey was carried out between October/November and March/April in the year 2000 and again in the same months in the year 2001, to obtain a broader verification of selected topics in the knowledge base over a wide cross section of farmers in the region.

The researcher and two other support staff conducted the questionnaire survey. Prior to being assigned to the job, the support staff were given orientation on methodological aspects and about the objectives of the project. From five to seven days were required to fill in and complete the questionnaire at each site.

There were two different questionnaires enumerated at different times. The first questionnaire conducted in 2001 was concerned with farmers' knowledge about feeding and management of tree fodders (Appendix 3.1) whilst, the second questionnaire mainly on dry season feeding strategies (Appendix 3.2) was conducted in the year 2002.

3.2.1.4.1 Questionnaire 1

This questionnaire aimed to investigate farmers' knowledge on feeding and management practices of tree fodders. This survey was conducted in Fakchamara, Fikkal, Sindhuwa, Patle and Solma with a total of 66 farmers. The number of farmers interviewed by site and wealth categories is presented in Table 3.4. Rich farmers are just sufficient or self sufficient in food production for at least one year. Poor farmers have food deficit for at least half the year.

Table 3.4 Numbers of farmers interviewed in a verification survey about feeding and management of tree fodders

Site	Rich	Poor
Fakchamara	10	10
Fikkal	5	4
Sindhuwa	8	10
Patle	6	4
Solma	4	5

The questionnaire included farmers' knowledge about tree species that remain green during the most critical dry period; leaf flushing months, feeding and lopping months for individual tree species and the characteristics of tree species in relation to dung or urine quality. The questionnaire also included questions as to how farmers define *obhanopan, posilopan* and *adilopan* terminologies and whether or not they practice mixing these three quality attributes of tree fodders. The questionnaire also included farmers' knowledge on whether or not the *obhanopan* quality of tree fodder changes with weather conditions and how and why farmers' supply particular tree fodder types to specific animal types.

3.2.1.4.2 Questionnaire 2

The second questionnaire was designed to investigate local strategies to cope with dry season shortages of fodder. The questionnaire also included farmers' knowledge about fodder quality as affected by weather conditions. It also included formats for ranking of tree fodders based on manure quality and fuel value.

The questionnaire was conducted with a total of 78 individual farmers in Dhankuta and Terhathum districts (Table 3.5) on topics identified from the informal interviews above. Dhankuta district covered Patle and other hamlets near Dhankuta district whilst, Terhathum district covered Basantapur and Fakchamara. These sites are distributed in a triangle about 5 to 6 hours walking distance from one another. Basantapur is located to the north, is relatively cooler and has the opportunity to produce vegetables and has large areas of government and public forest. Fakchamara is located on the east, has poor access to roads and consequently has less opportunity for commercial agricultural production and marketing.

Table 3.5 Numbers of farmers interviewed in a verification survey about dry season fodder shortages by site and gender

Site	Wards covered	Gender		Rich	
		Male	Female	Male	Female
Basantapur	5, 6, 7 and 9	12	12	6	6
Patle*	Patle (also covered some hamlets nearby)	20	10	11	5
Fakchamara	6, 8 and 9	12	12	6	6

*VDCs/hamlets covered were Bhirgaon, Chungbang, Patle, Nigale and Thapa tol.

The questionnaire included questions about local strategies for feeding management during the dry season considering use of dry roughages, low palatable fodder resources and management of animals. The answers of each farmer were recorded as 'yes or no' responses to a series of questions (Appendix 3.2). Farmers were also asked whether various things affected fodder. These included the effect of sunshine (sunny or shaded), wind (low or high) and soil moisture condition (low water content or dry land) on leaf fall, fodder quality, fodder productivity and lifespan of trees. During discussion with the farmers, it was noted that the *obhanopan* and *posilopan* characteristic of fodders were influenced by weather conditions.

A separate ranking exercise was, therefore, conducted in Patle in the year 2002 involving 20 farmers represented by 10 male (age 43-79) and 10 female farmers (age 31-72). The farmers were asked to rank tree species for *posilopan* and *obhanopan* separately for each major season, summer (mid February-mid October) and winter (mid October-mid February).

These same farmers (those 78 farmers answering the second questionnaire) were also asked to classify the 15 different tree species (Table 3.3 above) based on three locally defined categories of fuel value as follows.

- *Kharopan*: firewood that burns intensely with more energy and durability, that is, it burns for a long time giving a lot of heat. This is desirable.

- *Kafalopan*: firewood that burns quickly like paper. This is undesirable.

- *Pochopan:* firewood that burns slowly often spitting and producing heavy smoke. This is undesirable.

These farmers were also asked to evaluate the effects of feeding different fodder tree species on the quality of manure produced by animals and the subsequent effect of manure on soil fertility. Each farmer was asked to rank the tree species on the basis of the characteristics such as the manure quality of tree species *tikaupan*[9] of manure (*tikau/kamtikau*), leaf decomposition (slow or fast), dung solidness (solid or loose), dung heaviness (heavy or light) and transportation (easy or difficult).

[9] '*Tikaupan*' is the quality attribute generally applied to measure the strength of manure. The literal meaning of '*Tikaupan*' is the strength of manure that can at least sustain subsequent crop after its application to a first crop. Kam-tikaupan is opposite to '*Tikaupan*' i.e. the quality of manure whose manure value losses quickly thus requiring additional supply of manure to the subsequent crops.

Plate 3.3 Heaps of manure on *bari* land

Matrix ranking of 15 different fodder tree species based on overall parameters

Individual farmers were asked to rank from best (1) to worst (15) for 13 different parameters considered important for animal productivity and socio-cultural reasons. These were fodder value, fuel value, household use, ease of propagation, growth rate, leaf retention, ease of lopping, fodder yield, ease of carriage, lifespan of tree, *tapkan*[5] effect, disease susceptibility and manure value.

Farmers were asked to rank tree species for each parameter one after another. Ranking for each parameter was carried-out in the same fashion described above for ranking of most common tree fodders (Section 3.2.1.1.1). Rank scores of each tree species thus derived for each parameter were aggregated to derive the rank sum. The sum ranks were compared by age, wealth, gender and district using rank correlation.

[5] *Tapkan* is a Nepali term: the literal meaning is a process that causes splashes by raindrops from a tree leaf. *tapkan* causes splashes and erodes surface soil.

3.3 Statistical analysis

Difference in various desirable factors of tree fodders was evaluated in terms of age, gender and wealth categories of farmers. In order to examine the difference in the preference ranking of parameters by age, wealth, gender and site, the mean ranks of the individual parameters were combined and compared using rank correlation (Pearson's correlation coefficient) using Minitab version 13.1.

3.4 Results and Discussion

The knowledge base included 765 different statements, with 20 different taxonomic hierarchies of terms, the most important concerning animal types, tree fodders according to animal types, and fodder attributes. The knowledge base also included information about the lopping and flushing seasons of important fodder species. Eight topics were identified about farmers' practices for mitigating fodder deficiency and management of fodder resources during the critical period of fodder shortage. These included farmers' explanations on the effect of feeding *obhano-chiso, posilo-kamposilo* and *adilo-kamadilo* tree fodders. Key strategies to cope with seasonal shortage of green fodder included management of fodder and animals. The contents of the knowledge base are presented and explained in the following sections.

3.4.1 Local terminology for fodder quality attributes

Farmers recognised three major groups of fodder *barkhe ghans*, *hiunde ghans* and *garmi ghans* denoting their use in three different seasons: monsoon, winter and summer. These terms were consistently applied by farmers in the eastern hills and are also common in the Western hills of Nepal (Mrs. S. Acharya, *pers. Comm.*)[11]. Farmers used various terms to signify some fodder quality attributes that had similar underlying meaning. For example *syaule ghans*, *bekamme ghans*, *cheruwa ghans, dukhako ghans*

[11] Mrs. Sita Acharya, with farming background, a resident of Dihi danda, Khachikot ward-7, Arghakhanchi district western mid hills of Nepal

and *namitho ghans* were commonly used descriptive phrases whose meaning was roughly equivalent to the *kamposilo* quality attribute denoting low nutritional value as previously described (Section 1.5.1). The terms *syaule ghans, nikhurkama khuwaune, bekamme ghans* and *dukhako ghans* were used specifically for low quality fodders that are available during the most critical period of fodder shortage whereas *namitho ghans*, *cheruwa ghans* and *bekamme ghans* were used at anytime of the year for the fodder types with low palatability and that do not support health and nutrition of animals. Another term, *bakhre ghans*, also reported by Joshi, (1997) and Thapa, (1994) was used to denote species of fodder trees fed to goats and sheep. Another term *mitho ghans* (the opposite being *namitho ghans*) literally meaning 'tasty' was commonly used to refer to palatability of fodder. Carter, (1992) also reported the use of *mitho* and *namitho* terms to denote palatability and intake of fodder in the central mid hills of Nepal. There was evidence of animal specificity in ascribing fodder quality, in that some tree fodders, such as *painyu* (*Prunus cerasoides*), that were described as *namitho ghans* and so of low quality for cattle and buffalo, were said to be *mitho* (tasty) and *posilo* (nutritious) for goats and sheep.

The terms *posilo ghans* (nutritious) and *mitho ghans* (tasty) were sometimes used interchangeably and they were known jointly as *naram-kamalo ghans* (tender and soft) or more commonly *ramro ghans* (good). *Mitho ghans* was often associated with coarseness and bitterness of leaves that affect their palatability. It was understood that all *mitho ghans* (tasty fodders) were not necessarily *ramro ghans* (good fodders). For example, *dudhilo* (*Ficus nerrifolia*) was highly palatable but not a *ramro ghans* (good fodder) because it was not very *posilo* (nutritious). *khasre khanyu* (*Ficus semicordata* var *semicordata*) had coarse leaves, therefore, it was not palatable to animals, whilst, *dudhilo*, had smooth leaves and so was palatable to all animals while *painyu* was bitter in taste, and so was not palatable to large ruminants although it was palatable to sheep and goats. All *mitho ghans* (tasty fodders) were not necessarily *posilo* (nutritious) such as *dudhilo* (*Ficus nerrifolia*) and all *posilo ghans* (nutritious fodders) were not necessarily *mitho ghans* (tasty) such as *painyu* (*Prunus cerasoides*). Painyu was considered *posilo* (nutritious) for goats and sheep but not palatable to cattle and buffalo. All *ramro ghans* (good fodders), however, such as badahar (*Artocarpus lakoocha*) and malbans (*Bamboosa nutans*) were both *posilo* (nutritious) and *mitho* (tasty).

3.4.1.1 Local understanding of posilopan, obhanopan and adilopan

In addition to the previously described fodder quality attributes *posilopan* (nutritive value) and *obhanopan* (literally warm and dry, but associated with digestibility) (Thapa, 1994) the present study revealed a third key descriptor used by farmers, referring specifically to the duration of appetite satisfaction, *adilopan*. When the farmers were asked to define the terms *posilopan*, *obhanopan* and *adilopan* 195 different statements were obtained for *posilopan*, 213 for *obhanopan* and 193 for *adilopan*. The most common answers derived from 57 different farmers are listed in Tables 3.6, 3.7 and 3.8 for attributes associated with *posilopan*, *obhanopan* and *adilopan* respectively.

3.4.1.1.1 Posilopan

Most farmers used various terms to describe *posilo* fodders such as *poss lagne* (muscle building), *nirogi* (health promoting) and *ramro ghans* (good fodder). The most commonly used descriptions were *posilo ghans* and *ramro ghans* that were used interchangeably. The three most important attributes of *posilo* fodders where *dudh aune* (milk promoting), *ghieu lagne* (butterfat yielding) and *poss lagne* (health promoting) while high palatability and firm dung consistency was also frequently associated with *posilo* fodders (Table 3.6).

Table 3.6: Characteristics of *posilopan* described in 195 statements by 57 farmers comprising 17, 9, 7,10 and 8 respondents from Fakchamara, Fikkal, Sindhuwa, Patle and Solma VDCs respectively.

Characteristics of *posilopan* fodder	% of statements	% of farmers
Posilo fodders promote milk (*dudh aune*) and fat yield (*ghieu lagne*)	28.2	96.5
Posilo fodders are highly palatable (*ramayera khane*)	23.1	78.9
Posilo fodders improve animal health or make animals strong (*poss lagne*) and healthy	21.0	71.9
Animals fed on *posilo* fodder pass firm dung	14.4	49.1
Animals fed on *posilo* fodder gain weight and achieve quick growth	7.2	24.6
Leaves of *posilo* fodders are soft and smooth	2.1	7.0
Other various statements	4.0	14.4

Farmers' were aware of a range of consequences of feeding *posilo* fodder for animal health and productivity as well as the impact of its inclusion on the palatability and digestibility of rations (Figure 3.1).

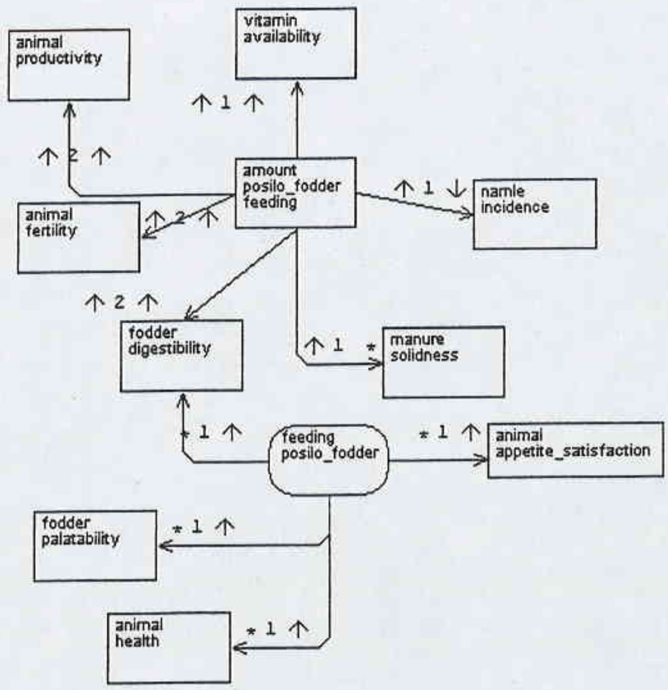

Figure 3.1 Systematic representation of farmers' causal knowledge about feeding *posilo* fodder (lower part of diagram) and more specifically, changing the amount of *posilo* fodder that is fed (upper part of diagram). Oblong nodes with sharp corners represent attributes of components in the system (such as 'solidness' of manure) while those with rounded corners represent actions (such as 'feeding'). Links between the nodes represent causal flow from one node to the other. The small arrows signify the direction of change of values of the causal node and the affected node (up arrow for increase and down arrow for decrease), a number 2 between the small arrows indicates two-way causation, meaning that the directions are reversible, so that an increase in x causing a decrease in y also implies that a decrease in x will cause an increase y, where as a number 1 indicates that causation is one-way only. A * indicates that a particular state of a node (for example 'high' fodder digestibility, is causal or affected rather than a change in the node. *Namle* is the local term for the liver disease, *fascioliasis* caused by a helminth parasite.

3.4.1.1.2 Obhanopan

Several different terms were used by farmers to describe *obhano* (warm) fodder such as *tato ghans* (hot), *nyano ghans* (warm). The converse of *obhano* is *chiso* (cold) but a range of other similar terms *thandi ghans* and *sardi ghans* (also meaning cold), *bekamme ghans* (useless), *cheruwa ghans* (causes diarrhoea) and *rogi ghans* (causes poor health) were also used. However, *tato ghans* (for *obhano* fodder) and *thandi ghans* (for *chiso* fodder) were the most widely used alternative terms. Other alternatives were specific to the location, for example *bekamme ghans* was common in Patle (Dhankuta district), *cheruwa ghans* in Mamling (Sankhuwasabha district), while *sardi ghans* and *rogi ghans* have been reported from Chitwan in the terai (Shrestha, 2000).

Some farmers reported that feeding very *obhano* fodder caused constipation[12] and feeding very *chiso* fodder caused animals to pass watery dung. Farmers had a clear understanding of the impact of feeding *obhano* fodder on animal thirst, water intake and urination as well as on health (Figure 3.2). Farmers thought that palatability of rations was increased by adding *obhano* fodders and they described an explicit linkage between *obhanopan* and *adilopan*.

Distinctions were made between tree fodders and crop residues; very-*obhano* fodders, locally referred to as '*sukkha ghans*' were the crop residues such as rice straw, maize straw, millet straw and maize sheathes. They also made a distinction that all '*sukkha* ghans' were *adilo* but not all *obhano* fodders were *adilo*.

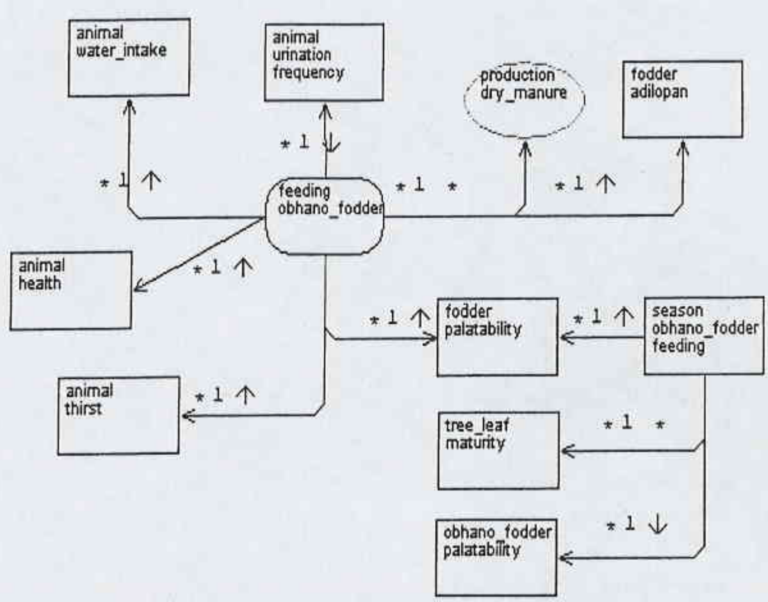

Figure 3.2 Systematic representation of farmers' causal knowledge about the consequences of feeding *obhano* fodder. Symbols as in Figure 3.1, with the addition that oval nodes represent natural processes (such as 'production' of dry manure by animals).

[12] Local expression for constipation was *sikka* (big coin) like hard dung.

The most important characteristics of *obhano* fodders were their high palatability and their impact on butterfat recovery (*ghieu lagne*) and dung quality (Table 3.7). *Obhano* fodders were reported to be highly palatable particularly during the cold, wet season. While feeding *obhano* fodder had no affect on milk yield (*dudh aune*) it was thought to increase the butterfat content of the milk that was produced. With respect to dung quality, *obhano* fodders were thought to promote firm, dry dung and so could cause constipation if fed in excess.

Generally *obhano* fodders such as *badahar* (*Artocarpus lakoocha), malbans (Bamboosa nutans*) and *ghotli* (*Grewia oppositifolia*) were lopped twice a year, the main harvest period was during the winter (mid October-mid February) but young leaves could also be fed during the summer (mid February-mid October). Farmers distinguished *obhano* fodder from *chiso* fodder by observing the texture of leaves. They reported that young *obhano* leaves were coarser than the young leaves of *chiso* fodder. They also distinguished them by their palatability and by examining the latex or water content of lopped branches or of cut leaves, with *chiso* fodders having high water content. They reported that *chisopan* of the leaves could also be assessed by simply crushing and rubbing the leaves between fingers to detect coarseness and water content. *Obhano* and *chiso* fodders could also be distinguished in some cases by observing the fodder selectivity of animals. Animals preferred to eat young twigs or stems of the coarse-leaved *chiso* fodders, such as *dudhilo* (*Ficus nerrifolia* var *nemoralis*) and *nebharo* (*Ficus auriculata*) which were more succulent than the leaves, whilst the leaves of *obhano* fodders such as *badahar*, *malbans* and *amliso* (*Thysanolaena maxima)* were more palatable than their twigs.

While there were some similarities in effects of *posilo* and *obhano* fodders, both were palatable, and associated with butterfat yield, firm dung and health, there were also clear distinctions and differences of emphases. Most farmers thought that *obhano* fodders promoted butterfat but not overall milk yield, whereas, *posilo* fodders promoted milk and butterfat yield and the impact of *obhano* fodders on palatability and dung consistency were more pronounced but impacts on health less pronounced than for *posilo* fodders. Also, *obhanopan* affected animal water intake and urination while *posilopan* was not associated with these.

Table 3.7: Characteristics of *obhanopan* described in 213 statements by 57 farmers comprising 17, 9, 7,10 and 8 respondents from Fakchamara, Fikkal, Sindhuwa, Patle and Solma VDCs respectively.

Characteristics of *obhanopan* fodder	% of statements	% of farmers
Obhano fodders are highly palatable (even in cold and wet season)	21.1	78.9
Animals fed on *obhano* fodder pass solid, dry and warm dung, sole feeding causes constipation	18.3	68.4
Obhano fodder does not cause a change in milk volume but causes an increase in butterfat content - the milk becomes denser, *ghieu lagne*	15	56.1
Obhano fodder improves health of animals	8.5	31.6
Causes reduction in milk volume but an increase in butterfat content	7	26.3
Animals fed *obhano* fodder urinate less frequently	6.1	22.8
Animals fed *obhano* fodder gain weight	5.6	21.1
Causes an increase in milk volume but butterfat content unchanged	3.3	12.3
Causes both an increase in milk and butterfat content	2.3	8.8
Animal shed becomes dry and clean shed	1.4	5.3
Obhano leaves are lighter than *chiso* leaves	1.4	5.3
Other various statements	8.0	29.8

3.4.1.1.3 *Adilopan*

During discussions with the local people about *obhano* fodders, the terms *daro ghans* (strong) and *adilo ghans* (satisfying) were frequently used by local farmers. *Adilopan* was the more commonly used term in all the study sites and was specifically related to the duration of appetite satisfaction, in terms of rumen retention time and consequent reductions in hunger and fodder requirement (Figure 3.3).

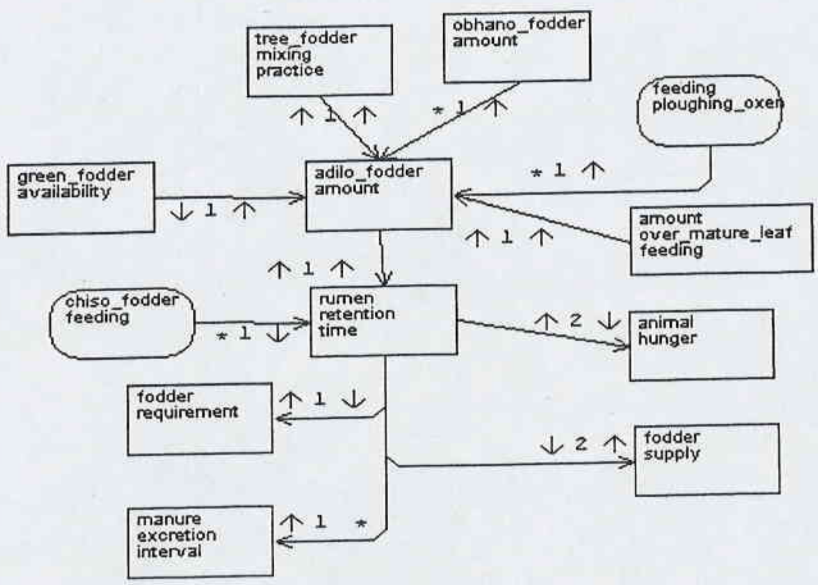

Figure 3.3 Systematic representation of farmers' causal knowledge of the consequences of feeding *adilo* fodder. Symbols as in Figure 3.1.

Farmers' were less consistent in defining *adilopan* than either *obhanopan* or *posilopan* but the overriding attribute of *adilo* fodder was that it satisfied appetite for a long time (Table 3.8). About 14% of the total descriptions for *adilopan* (in the 'other' category in Table 3.8) were idiosyncratic answers not frequently enough encountered to be classified as in common usage.

Table 3.8 Characteristics of *adilopan* described in 193 statements by 57 farmers comprising 17, 9, 7,10 and 8 respondents from Fakchamara, Fikkal, Sindhuwa, Patle and Solma VDCs respectively.

Characteristics of *adilo* fodders	% statements	% farmers
Adilo fodder satisfies appetite of animals for a long time	21.8	38.2
Adilo fodder improves animal health (slowly but not rapidly)	13.5	23.6
Animals fed on *adilo* fodder pass solid and dry dung	9.8	17.3
Adilo fodder fills the gut (*pet ukasne*) and stays longer in the rumen (digests slowly)	9.3	16.4
Palatable (but less palatable than *obhano* or *posilo* fodder)	8.8	15.5
Adilo fodder does not effect milk yield but there is a slight increase in butterfat yield	7.3	12.7
Slight increase in butterfat yield	4.7	8.2
Milk becomes dense and slight increase in butterfat	4.1	7.3
Does not change on milk yield	2.6	4.5
Slight increase in milk and butterfat yield	2.1	3.6
Slight increase in milk yield	2.1	3.6
Other various statements	14	24.5

3.4.1.2 Discussion

Farmers distinguished *posilopan* from *obhanopan* or *adilopan* fodder by observation of an increase in milk and butterfat production, which were the most important characteristics of *posilo* fodders. Increase in milk or butterfat production, increase in palatability, improved vigour and health, the key characteristics of *posilo*pan fodders, were similar to the characteristics reported by Solma farmers (Thapa, 1994) in the eastern mid hills. These main characteristics were also similar to the characteristics reported by farmers in the western mid hills (Gurung, 2001) and central mid mills (Rusten, 1989) of Nepal as being typical of nutritious fodder. Walker *et al.* (1999) also reported that the low fibre, low tannin and low dry matter that they measured in fodders that farmers described as *posilo* were consistent with the farmers' description of *posilo* fodder.

Consequences of feeding *obhano* or *chiso* fodders for animal performance and dung quality recorded in this study generally corresponded with the reports of earlier workers (Rusten, 1989; Carter, 1992, Thapa, 1994 and Joshi, 1997). Beside the visible impact on animals such as loose dung and increased frequency of urination (Thapa, 1994), local farmers distinguished *obhano* or *chisopan* of tree leaves from an estimation of the amount of water they contained. Terms such as *rogi* and *nirogi ghans* have been reported as synonyms for *posilo* and *kamposilo* fodders in Chitwan district in Central Nepal (Pande and Neopane, 1995). The farmers in Chitwan are recent migrants from the western and central mid hills and their knowledge is likely to have derived from their experience of hill farming. Similarly, the *garmi-sardi* terms used by farmers of Chitwan to differentiate quality of tree fodders (Pande and Neopane, 1995) was similar in definition to the *chiso-obhano* terms used by eastern hill farmers. Similar to the eastern hill farmers, farmers of Chitwan district differentiated between *obhano* and *chiso* fodders from the relatively dry, stiff and leathery leaves of *obhano* fodder and succulent, smooth and heavier leaves of *chiso* fodders. The *chiso-obhano* characteristics defined by the farmers of eastern hills also agreed fairly well with the farmers of Parbat district in western hills (Rusten and Gold, 1991) and with farmers of Chitwan district (Pandey and Neopane, 1995). Rusten and Gold (1991) reported that *chiso* fodders were often considered to be of poor quality, sole feeding of which could cause deleterious effects to animals such as *bakaino* (*Melia azedarach*), which if used as a sole feed could cause choking. They also reported that highly *chiso* fodders were fed only in limited quantities and were often mixed with *obhano* fodders. *Chiso* fodders were not necessarily *kamposilo* (of low nutritive value). Rusten and Gold (1991) reported that *pani lahara* (*Tetrastigma serrulatum*) considered to be one of the most *chiso* fodders, was most popularly used in Parbat district to enhance production of milk and butterfat. Firmness of dung that an animal produced was another important characteristic of an *obhano* fodder.

Thorough discussion with the farmers about *obhanopan* led to the discovery of another term *adilopan*, which was more specifically applied to a feed type that would satisfy appetite and control behaviour of animals. Joshi (1997) also reported the term *adilopan* being associated with the passage of digesta (duration of appetite satisfaction) and feed requirements in line with the characteristics described by most farmers in this study. However, only 0.5% (of the 221 farmers) in his study reported that *adilo* was an important attribute influencing fodder quality. The additional statements in this study that *adilo* fodders were less palatable and less nutritious compared to *obhano* fodder supports the explanation of *adilo* fodder being slowly digested and filling animals.

3.4.2 Ranking of tree fodders in terms of *posilopan*, *obhanopan* and *adilopan*

Farmer ranking of fodders for different attributes was summarised by calculating a percentage rank score. This is the percentage of the maximum possible score, which is a function of the number of species ranked and number of rankings. For each ranking event the highest ranked species (1) gets a score equivalent to total number of species ranked (e.g. 15) and the next, one less (14) and so on down to the lowest ranked species that gets accorded a score of 1.

3.4.2.1 Ranking of obhanopan *and* adilopan

There was a strong rank correlation (r_s) between the mean overall ranking of the 15 fodder trees for *adilopan* and *obhano*pan (r=0.912, p=0.000), indicating that in general more *obhano* fodders were also more *adilo* (Table 3.9).

Table 3.9 Mean overall % rank score (standard deviation shown in brackets) of tree species for *obhano*pan and *adilopan* by all farmers

Tree species	*Obhanopan*	*Adilopan*
Malbans	91.7 (5.98)	90 (5.83)
Amliso	88.9 (2.88)	92.8 (1.53)
Badahar	76.7 (3.81)	81.7 (3.68)
Khasre khanyu	73.9 (3.43)	60 (6.25)
Tanki	72.2 (3.56)	73.9 (3.12)
Rai khanyu	70.6 (4.14)	68.9 (3.42)
Rato siris	57.2 (2.39)	45 (4.58)
Patmiro	50.6 (5.89)	52.8 (6.89)
Bhimsenpati	47.8 (7.15)	26.7 (4.78)
Nebharo	44.4 (8.18)	62.2 (6.37)
Kabro	31.1 (3.51)	42.2 (4.37)
Chuletro	30.0 (4.30)	26.1 (3.43)
Gogun	25.6 (4.25)	35.6 (3.96)
Painyu	23.3 (6.22)	17.2 (7.13)
Dudhilo	16.1(2.24)	25 (3.68)

There were however a few species (*khasre khanyu, rato siris* and *bhimsenpati*) that were noticeably more *obhano* than *adilo* and others (*nebharo, kabro* and *gogun*) that were much more highly ranked for *adilopan* than they were for *obhanopan* (Figure 3.4).

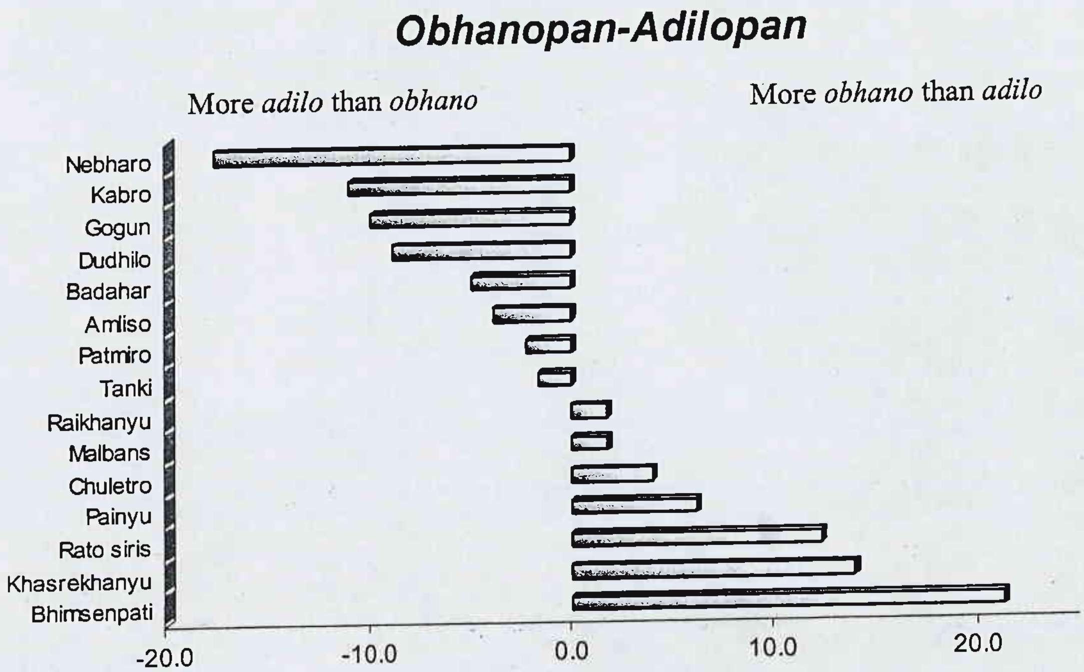

Figure 3.4 Difference in mean *obhano* and *adilo* rank scores for each species

The species that were more *obhano* than *adilo* were all quite highly *obhano*, with dry leaves, but were not standard cattle fodder. *Bhimsenpati* was mainly used as a sheep and goat rather than a cattle fodder, *khasre khanyu* was only considered palatable when leaves were young and rato siris was known to only produce a low biomass yield, indicating that farmers perceived these as less able to satisfy appetite in general terms even though they were *obhano*. In contrast all the fodders that were more *adilo* than *obhano* were *chiso* fodders (low in their *obhano* score) and described as wet but were nevertheless associated with high intake that might be expected to satisfy appetite.

3.4.2.1.1 Variation in the ranking of obhanopan and adilopan between study sites

Pairwise rank correlations were significant for both *obhanopan* and for *adilopan* amongst all pairs of sites but the strength of concordance was generally higher for *adilopan* (rs 0.735 to 0.941) than *obhanopan* (rs 0.694 to 0.915). Generally there was less consistency amongst sites for lower ranked species for both *obhanopan* (Figure 3.5) and *adilopan* (Figure 3.6).

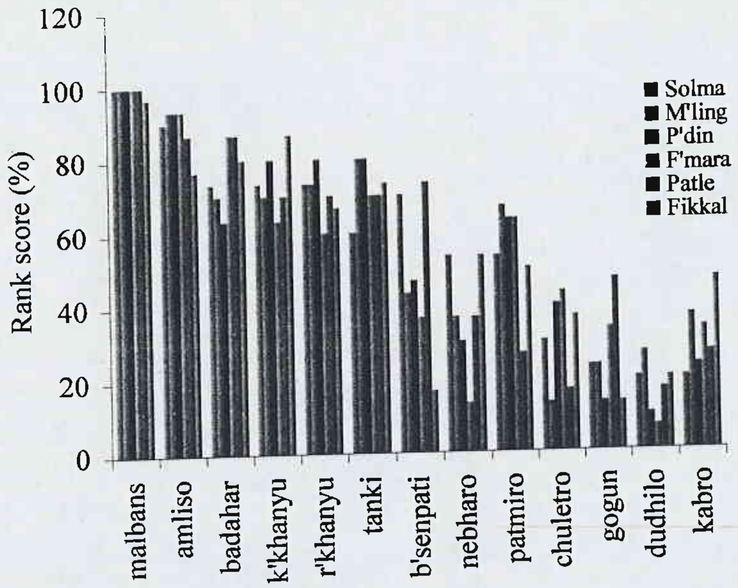

Figure 3.5 Variation among sites on ranking of *obhano-chiso*pan of tree fodders

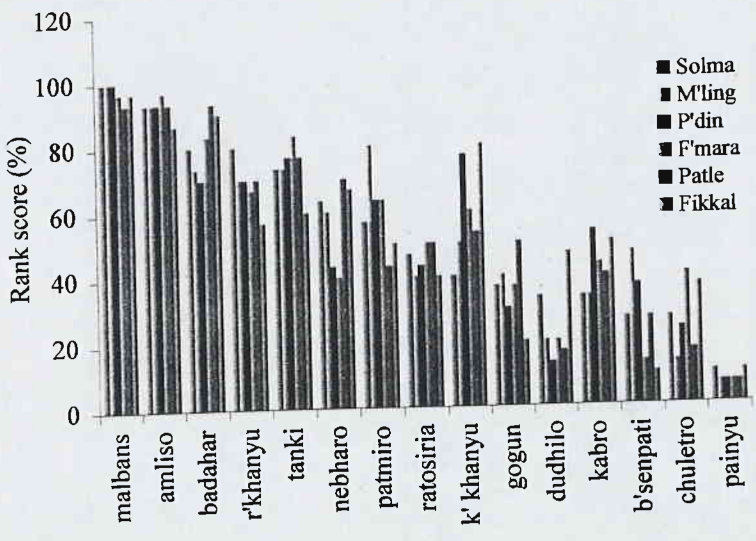

Figure 3.6 Variation among sites on ranking of *adilo-kamadilopan* of tree fodders

There was no systematic variation in terms of which pairs of sites had higher rs values for either *obhanopan* or *adilopan*. Rankings by men and women were also highly correlated for both attributes (rs 0.948 and 0.938 for *obhanopan* and *adilopan* respectively) but there were some noticeable differences attributable to gender (Table 3.10).

Table 3.10 Mean percent rank scores for some tree species that were ranked differently by men and women for *obhanopan* and *adilopan*

Tree species	*Obhanopan*		*Adilopan*	
	Male	Female	Male	Female
Bhimsenpati	40	55.6		
Kabro			35.6	48.9
Khasre khanyu			67.8	52.2
Nebharo	40	48.9	54.4	70
Painyu	18.9	27.8		
Rato siris			51.1	38.9
Tanki	80	64.4	78.9	68.9

3.4.2.2 Ranking of posilopan of tree fodders

Overall ranking of fodders for *posilopan* were clearly different from those for *obhano*pan or *adilo*pan (Table 3.11). While some fodders were highly *posilo, obhano* and *adilo* such as *malbans, badahar* and *amliso*, others were highly *posilo* but not very *obhano* or *adilo* such as *nebharo* and *kabro* while others were not very *posilo* but highly *obhano* and *adilo* such as *khasre khanyu*.

Table 3.11 Mean overall percent rank store (standard deviation in brackets) of tree species for *posilopan*.

Tree species	% rank score
Malbans	87.8 (5.96)
Badahar	87.2 (3.01)
Amliso	84.4 (6.16)
Nebharo	72.2 (4.84)
Rai khanyu	64.4 (3.96)
Rato siris	64.4 (6.10)
Kabro	61.1 (4.63)
Tanki	60.6 (5.59)
Patmiro	48.9 (6.16)
Dudhilo	38.3 (4.03)
Khasre khanyu	31.1 (3.42)
Chuletro	30 (5.09)
Gogun	28.9 (3.21)
Bhimsenpati	21.7 (4.58)
Painyu	18.9 (7.58)

As for *obhanopan* and *adilopan* there was generally more consistency in ranking amongst sites for more *posilo* fodders (Figure 3.7).

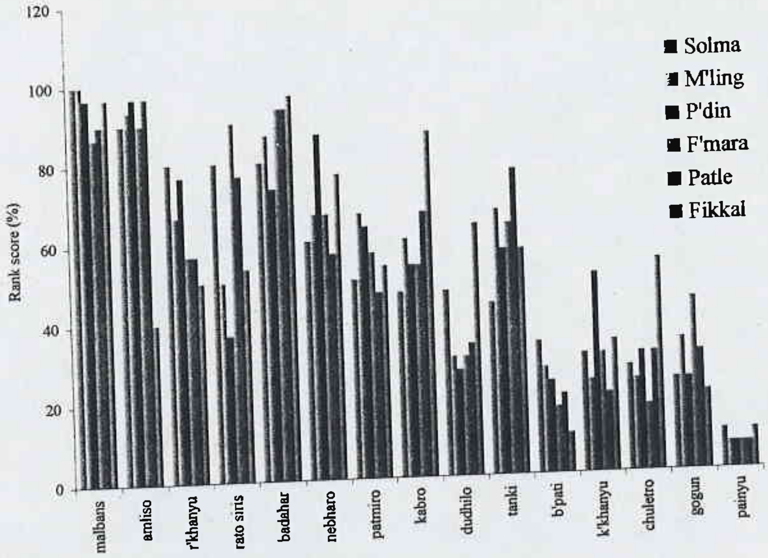

Figure 3.7 Variation among sites in the ranking of *posilo-kamposilopan* of tree fodders

Pairwise comparisons of *posilo*pan rankings amongst sites were all significantly correlated, but there was a clear pattern in that Fikkal had lower concordances than all other sites (Table 3.12).

Table 3.12 Pairwise comparisons of *posilopan* rankings amongst sites

	Mamling	Fikkal	Patle	Sindhuwa	Fakchamara
Fikkal	0.690 0.004				
Patle	0.926 0.000	0.700 0.004			
Sindhuwa	0.916 0.000	0.625 0.013	0.779 0.001		
Fakchamara	0.897 0.000	0.634 0.011	0.947 0.000	0.771 0.001	
Solma	0.878 0.000	0.624 0.013	0.871 0.000	0.816 0.000	0.884 0.000

Cell Contents: Pearson correlation
P-Value

3.4.2.3 Combined ranks of tree fodders

The ranking for *posilopan*, *obhanopan* and *adilopan* attributes were combined in an overall mean to derive a general preference rank for tree fodder (Figure 3.8). *Malbans, amliso* and *badahar* had high combined scores (rank score from 82% to 90%) whilst, *painyu, dudhilo, chuletro, gogun* and *bhimsenpati* all had low scores (rank score from 20% to 32%).

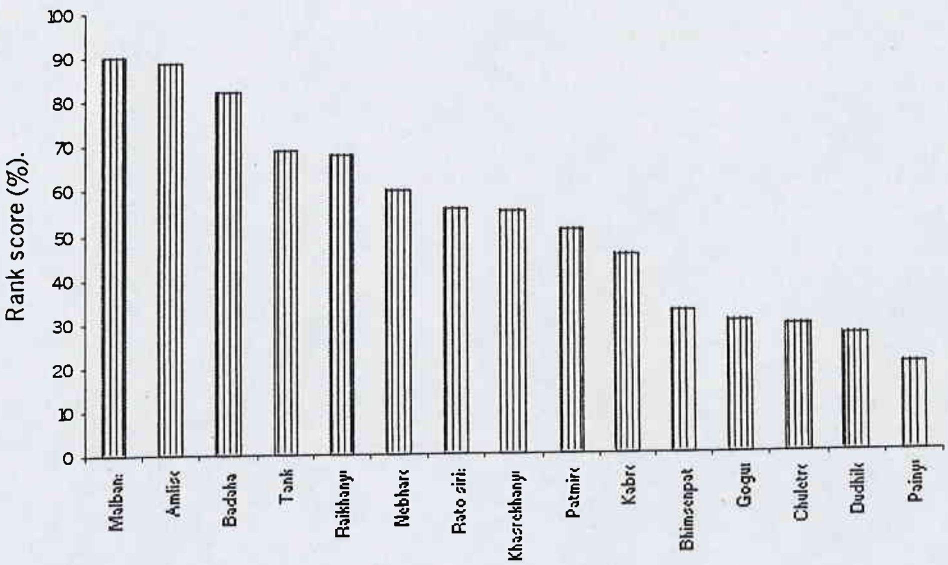

Figure 3.8 Rank orders of tree fodders considering *posilo, obhano and adilo* quality attributes

3.4.3 Seasonality of *obhanopan* and *chisopan* attributes of tree fodders

A total of twenty farmers (five male and five female in both summer and winter) were asked to rank 23 different tree species separately by season (summer and winter) in terms of *posilopan* and *obhanopan*, to explore whether farmers thought that the quality of tree fodder was affected by season or weather conditions.

3.4.3.1 Seasonality of **obhanopan** *and* **posilopan**

3.4.3.1.1 Obhanopan (or chisopan)

There were small changes in farmers' ranking for *chiso-obhanopan* with season for some tree species such as *painyu (Prunus cerasoides)*, *gogun (Sauruia nepaulensis)*, *dar (Boehmeria regulosa)*, *malbans (Bamboosa nutans)*, *badahar (Artocarpus lakoocha)* and *dudhilo (Ficus nerrifolia* var *nemoralis)*. Of the twenty-three different tree species, eight were ranked more *obhano* in winter than in summer and the others were ranked higher in summer than in winter. The rank scores for *ghotli (Sambucus hookeri), bhimsenpati, kunyel* (*Trema orientalis*) and *khasre khanyu* (*Ficus semicordata var semicordata)* were notably higher in winter than in summer (rank difference > 36). In contrast, the *obhano*pan of other tree species such as *kimbu (Morus alba), khari (Celtis australis), kabro (Ficus lacor), nebharo (Ficus nerrifolia), patmiro (Litsea monopotela)* and *chamlayo* (botanical name unknown) was higher in summer than in winter (rank difference > 28). Tree species with large variation (rank score >10) in *obhanopan* rankings between seasons are shown Figure 3.9.

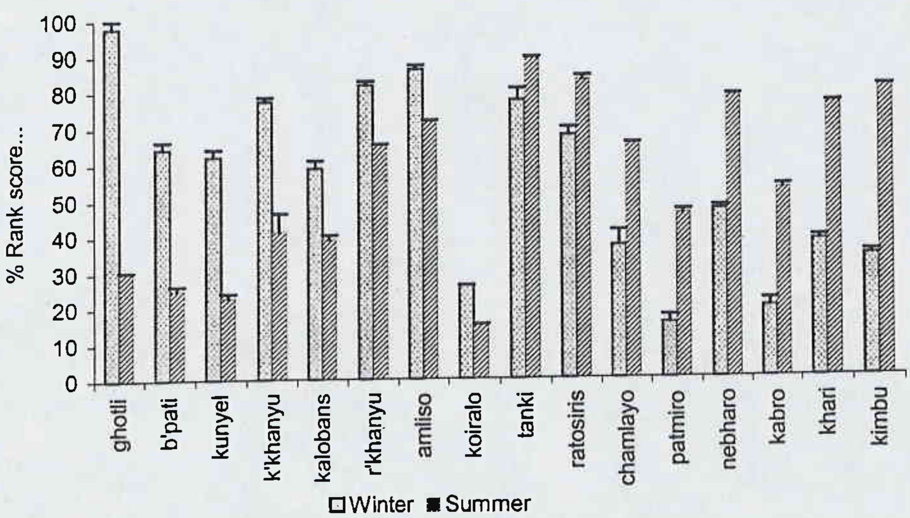

Figure 3.9 Overall mean rank scores of fodder types with seasonal differences in *obhanopan* >10 percentage points (equivalent to more than one rank position). Twenty farmers in four groups of five, ranked 23 species. The higher the score, the more *obhanopan* is the species.

There were no apparent differences in the ranking for *obhano* according to gender in summer, but in winter considerable variation was observed between the ranking of male and female farmers for nine species (Table 3.13). Female farmers ranked *chamlayo,* *kabro*, *malbans* and *rato siris* (*Albizia julibrissin*) as more *obhano* than male farmers, whilst male farmers ranked *ghotli*, *kalobans*, *patmiro*, *dar* and *tanki* as more *obhano* than female farmers.

Table 3.13 Overall mean rank scores of fodder trees with differences in *obhanopan* >5 percentage points (equivalent to more than one rank position) between male and females.

Tree species	Male (SD)	Female (SD)	Ranking difference (male – female)
Tanki	80.4 (9.22)	73.9 (0.0)	6.5
Dar	43.5 (0.00)	37.0 (9.2)	6.5
Ghotli	100.0 (0.00)	95.7 (6.1)	4.3
Kalobans	60.9 (6.15)	56.5 (0.0)	4.3
Patmiro	17.4 (6.15)	13.0(0.0)	4.3
Rato siris	65.2 (6.15)	69.6(0.0)	-4.3
Kabro	17.4 (6.15)	21.7(0.0)	-4.3
Malbans	93.5 (3.07)	97.8 (3.1)	-4.3
Chamlayo	30.4 (0.00)	43.5 (6.1)	-13.0

3.4.3.1.2 Posilopan (or kamposilopan)

Farmers' ranking for *posilo* to *kamposilo* changed according to season for some species (Figure 3.10).

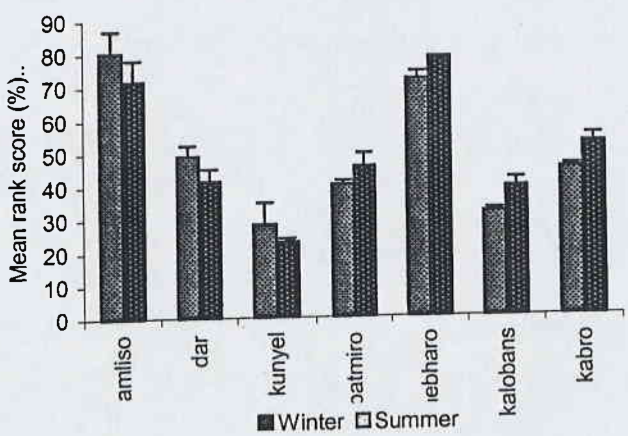

Figure 3.10 Overall mean rank scores for *posilopan* of fodder types with seasonal differences of >5 percentage points (equivalent to more than one rank position). Twenty farmers in four groups of five, ranked 23 species.

Patmiro, nebharo, kabro and *kalobans* (*Bamboosa hookeri)* were ranked as more *posilo* in summer than in winter whilst *amliso (Thysanolaena maxima)*, *dar* and *kunyel* (*Trema orientalis*) were ranked as more *posilo* in winter than in summer.

In summer, as for *obhanopan*, male and female farmers ranked fodders similarly but their ranking for *posilo*pan differed slightly in the winter (Table 3.14). Female farmers ranked *khasre khanyu* and *amliso* as more *posilo* compared to the male farmers, whilst male farmers ranked *nebharo, painyu, dar, kimbu* and *kunyel* as more *posilo* than female farmers.

Table 3.14 Overall mean rank scores of fodder trees with differences in *posilopan* >5 percentage points (equivalent to more than one rank position) between male and females.

Tree species	Male (SD)	Female (SD)	Ranking difference (male – female)
Kunyel	34.8 (18.4)	21.7 (0.0)	13.0
Kimbu	80.4 (9.2)	73.9 (0.0)	6.5
Dar	52.2 (0.0)	45.7 (9.2)	6.5
Nebharo	73.9 (6.1)	69.6 (0.0)	4.3
Painyu	15.2 (3.1)	10.9 (9.2)	4.3
Rato siris	78.3 (6.1)	82.6 (0.0)	-4.3
Amliso	73.9 (18.4)	87.0 (0.0)	-13.0
Khasre khanyu	34.8 (18.4)	50.0 (3.1)	-15.2

3.4.3.2 Seasonality of **posilopan** *attributes of* **obhano** *or* **chiso** *tree fodders*

The 23 different tree species were grouped into two by *obhano* and *chiso* attributes, and the same groups of farmers (Section 3.1.1) were asked to rank separately by season (summer and winter) in terms of *posilopan*, to explore whether farmers thought that the quality of *obhano* and *chiso* attributes of tree fodders was affected by season.

3.4.3.2.1 Seasonality of posilopan *attribute of* obhano *tree fodders*

There were small differences in the ranking of *posilopan* of *obhano* fodders for *kalobans* and *bhimsenpati* (rank difference <2.3). Of the 11 different *obhano* tree fodders, the species that had large differences in *posilo* rankings were *rato siris* and *kunyel* (rank difference >10). *Rato siris* was ranked more *posilo* during winter whilst *kunyel* more *posilo* in summer than in the winter. All other tree species had similar, relatively lower rank differences, the majority of them were ranked more *posilo* during winter than in the summer (Figure 3.11).

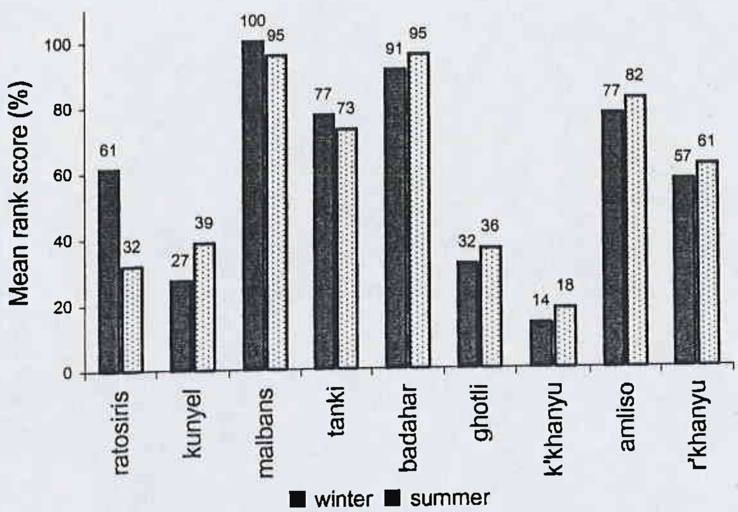

Figure 3.11 Difference in farmers' ranking of *posilopan* of *obhano* tree fodders between seasons (only ranking differences >3 shown)

3.4.3.2.2 Seasonality of posilopan *attribute of* chiso *tree fodders*

Of the twelve *chiso* fodder tree species, there were only small differences in the *posilopan* rankings between seasons for the species *patmiro*, *chuletro* and *kabro*. The difference in ranking of *koiralo, gogun* and *dar* was particularly large between seasons. *Koiralo* was ranked as more *posilo* during winter than summer, whilst *gogun* and *dar* were ranked more *posilo* during summer than winter (Figure 3.12).

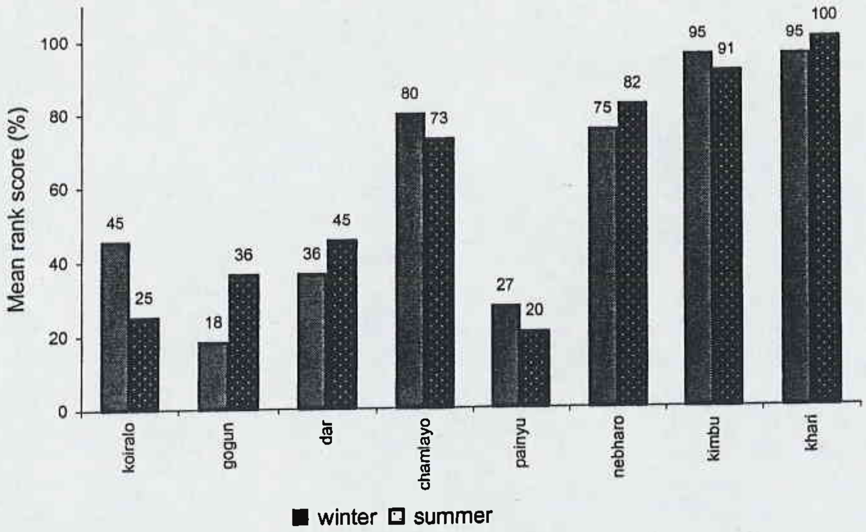

Figure 3.12 Difference in farmers' ranking of *posilopan* of *chiso* tree fodders between seasons (only ranking differences > 4 shown).

3.4.3.3 Resolving conflicting statements

Some apparently conflicting statements amongst farmers were later resolved through further questioning while others that remain may reflect specific practices and circumstances faced and followed by individual farmers. For example, initially conflicting statements that either *adilo* or *posilo* fodder were appropriate for oxen were reconciled when it was revealed that two different types of fodder were fed to draft animals at different times of day. It was common practice to feed *adilo* fodder when oxen were working, *posilo* fodder immediately after work and then *adilo* fodder again when not working. A farmer in Patle explained that this was because feeding *chiso* or *kamadilo* fodder to working animals was problematic because they are rapidly digested causing frequent excretion of dung, that requires time consuming removal before work can recommence. It is already known that labour is one of the important constraints in hill farming systems in Nepal. Nepal is a land of people with diversified socio-cultural, ethnic and multilingual backgrounds and so care was required to understand equivalent terms for the same species. The languages vary from one ethnic group to another leading to differences in dialect for the common Nepali language. This leads to differences in the local names of fodder trees from one place to another (Appendix 3.3).

For example, the local name for *Sambucus hookeri* was *ghotli* in most of Dhankuta district but it was known as *ghorli* amongst Rai communities in Chintang VDC.

3.4.4 Discussion

The modest differences evident in the ranking of tree fodders for various quality attributes amongst farmers could be expected to arise from differences in perception of the attribute, differences in circumstances that affect the comparison amongst species or differences in how elements of the composite attributes are valued by different people.

Differences in perception

There were differences in what people did to judge how *obhano* or *chiso* different fodders were. Some farmers reported that they could identify the *obhano-chiso* characteristics from the firmness of resulting dung while others reported that they did so by examining the water content of the leaves. These different evaluation procedures might lead to differences in perception of the attribute. Similarly women, who are normally responsible for milking, generally judged *posilopan* in terms of milk yield whereas men, normally responsible for selling milk, were more likely to judge on the basis of butterfat content. In contrast, *adilopan* appeared to be a less composite attribute that was directly evaluated in terms of the time that animal appetite was satisfied rather than indirectly in terms of tactile investigation of the fodder. The common use of *adilopan* to describe fodder quality by farmers in the present study was not evident in previous research where only a few farmers (<2%) in the eastern hills mentioned it (Joshi, 1997). This may reflect differences in how farmers were questioned.

Differences in values and circumstances

Differences in ranking between genders and amongst sites might reflect differences both in circumstances and the relative importance put on different aspects of composite attributes or inclusion of more general preferences for species affecting the ranking process.

Gender

Differences in ranking for the three local attributes of fodder quality are summarised in Table 3.15.

Table 3.15 Differences in ranking for the three local attributes of fodder quality (difference between the rank score of males from females)

Tree species	*Obhanopan*	*Adilopan*	*Posilopan*
Tanki	15.6	10	25.5
Nebharo	-8.9	-15.6	-8.9
Bhimsenpati	-15.6		-10
Chuletro			-11.2
Kabro		-13.3	-11.1
Malbans			11.1
Patmiro			11.1
Rato siris		12.2	

Consistent differences in rankings for all three descriptors by men and women for some tree species particularly *tanki* (*Bauhinia purpurea*) and *nebharo* (*Ficus auriculata*) (Table 3.15) may indicate that women are modifying their ranking for nutritive value by incorporating other tree attributes in their assessment. Generally, in the absence of men, women are involved in lopping of tree fodder and feeding it to the animals. Tree species like *bhimsenpati* are small and women are able to harvest fodder from it easily. Other trees such as *rato siris, malbans* and *patmiro* are more difficult to harvest since they are either tall (*rato siris)*, have weak branches that are liable to break (*patmiro*) or require considerable manpower and skill to harvest (*malbans*), which may result in women reducing the value they accord these species as fodder. Women are also involved in household work, including using some tree leaves (such as *nebharo*) to make plates for ceremonial meals and shoots of other trees (such as *kabro*) as vegetables or salad and this may lead to the value they accord to these species because of their secondary uses impacting their assessment of their value as fodder.

Difference in rankings between male and female farmers could also be due to differences in responsibility and experience. Singh (2000) also reported that women have the most responsibility for raising livestock (at least 70% of total workload) and devote considerable amount of time and energy to collect fodder (Mahat *et al.,* 1987). Female farmers are generally involved in milking the animals, whilst male farmers are responsible for selling the milk. This division of labour might have developed their skills in understanding of milk or butterfat promoting fodder tree species separately, consequently causing a difference in the knowledge holding between the two. Male farmers ranked tree species such as *malbans, tanki* and *patmiro* (known to promote more butterfat) as more *posilo* compared to the females, whilst females ranked *nebharo* (known to promote high milk yield) as more *posilo* than the males. Rusten (1989), while conducting preference ranking of tree species found significant disagreements in opinions between the male and female farmers in their first preference whilst the differences were less evident for lower ranked species. However, in this study, the converse was found, that in general there was agreement amongst men and women at the extremes regarding the highest and lowest ranked species. This may reflect, notwithstanding some interference of other attributes, that farmers were more specifically ranking tree species for specific attributes (*posilopan*, *obhnaopan* and *adilopan*) in this study rather than expressing a more overall preference as appears to have occurred in previous research.

Season

Some tree species were ranked more *obhano* in the winter and others were ranked more *obhano* in the summer. These differences in rankings are perhaps related to farmers' management of individual trees. Trees are harvested at different times of the year depending upon the nature of their leaf shedding characteristics and according to needs and circumstances of the farmers. Harvesting of some tree species is also dependent on the altitudinal ranges at which they are available. Differences in farmers' ranking for *obhano* tree species could, therefore, be related to difference in lopping practices and the resultant changes in the flushing and maturity of the leaves. Lopping practices may vary from one location to another because of differences in leaf retention. For example species such as *nebharo, khasre khanyu* and *tanki* mature late at upper mid hill altitudes (>1400 m) and are lopped for longer periods than they are at low altitude.

Farmers' ranking between seasons did not differ strongly for species that are generally utilised throughout the year such as *gogun*, *dudhilo* and *painyu* and tree species that are regarded most *obhano* such as *malbans* and *badahar*. Some possible reasons for differences in ranking of *obhanopan* and *posilopan* between genders were discussed above and may have seasonal dimensions.

Rusten (1989) stated that the *obhano* fodders were mainly considered to be of good quality and *chiso* fodders generally of poorer quality. However, this study revealed that the value of *obhano-chisopan* attributes is seasonally dependent. Farmers' understanding that immature or over mature leaves are unpalatable and *kamposilo* to animals also suggested that the palatability and *posilopan* of these tree fodders are associated with season. As a result one might anticipate that some changes in attributes might be taking place along with changes in season. *Obhano* fodders generally identified as *posilo* changed to *kamposilo* if leaves senesced or when the leaves were immature. Thapa *et al.* (1994) reported a similar explanation by farmers in his study at Solma. Patle farmers in the present study reported that the leaves of *khasre* (coarse leaved) *khanyu* were highly palatable and *posilo* when young but could have a detrimental effect on animal productivity if they were fed during Feb-March when over-mature. Leaf maturity as a factor influencing fodder quality is consistent with various scientific studies that have revealed that young or over-mature leaves are associated with an increase in polyphenolics, decreasing palatability and restricting animals from the full utilisation of nutrients (Singh, 1998; Subba 1998, Wood *et al.,* 1994; Subba and Tamang, 1990).

Consistency in the evaluation by sites

Local topography and altitude might influence farmers' selection and ranking processes of tree fodders particularly for *obhano-chiso* criteria. Joshi (1997) indicated that farmers' assessment of *obhano* and *chiso* attributes depended on altitude, in that *obhano* fodders were more desirable at higher altitudes (above 1500 m) whilst *chiso* fodders were more valued at low altitudes (below 1100 m). Even within a day at a single site, farmers in the present study reported that the intake of *chiso* fodder would be lower if the animals were fed in the morning when it was cold but their intake of *chiso* fodder would go up during the day as the weather gradually became warm. Depending on weather conditions farmers feeding and management decisions were also reported to vary even within a day. Similar understanding and practices of farmers has been reported from Syangja district in the western mid hills of Nepal (Gurung, 2001). Sometimes farmers seemed to be coupling intake with *posilopan* in as much as tree fodders with high intake were considered as *posilo* fodder. Some farmers reported that intake of *chiso* fodders was low during the cold season and hence they were considered as *kamposilo* at this time but when the intake of *chiso* fodder becomes high in the warm season, they also become *posilo* fodder. It is anticipated that these perceptions of farmers might reflect associated negative effects of feeding *chiso* fodders during the cold season, such as diarrhoea, frequent urination and dullness of animals (Section 3.1.1). These temperature and weather dependent influences on farmers ranking could be expected to alter with local topography and microclimatic variations.

Differences in the farmers' ranking between study sites could also have arisen because of differences in the feeding and tree and animal management practices. For example, *amliso* is used solely for fodder in Dhankuta whilst it is used primarily for making brooms and only the residues are available for feeding to the animals in Fikkal in Ilam district. The clear difference in the ranking of *posilopan* of *painyu* (*Prunus cerasoides*) by Fikkal farmers from the other sites could be associated with the effects they have observed it to have on goat nutrition as opposed to feeding it to other livestock types. In Fikkal, *malbans* was not utilised as extensively for fodder as it was in the other sites. Although *malbans* is known as a highly *posilo* fodder in most sites, it was only an average type of *posilo* fodder in Fikkal. Likewise, not many farmers in Fikkal knew *patmiro*, and the difference in the ranking could have been as a result of it being less common there. Similarly, the ranking of *rato siris* by farmers in Sindhuwa, perhaps reflects that it is less commonly available in this area. *Dudhilo* considered as a *posilo* tree species in Danda bazaar, Dhankuta was considered *kamposilo* in Patle. This was explained by sub-species variation, the *dudhilo* in Patle had smaller leaves than that found in Danda bazaar. This reflects a consistent local recognition of subspecies variation found previously for several species (Thapa, 1994; Joshi, 1997).

The difference in the ranking between sites could also be because of the variation in marketing opportunities, availability of other fodder and feed resources and requirements for specific outputs. Due to opportunity of generating income from milk animals, there are a growing number of crossbred animals in Patle and Sindhuwa, resulting in changes in the feeding and animal management systems (Section 2.3.4). It is likely that these changes might have also affected in the farmers' ranking of tree fodders. Milk and butterfat, the determinant factors for the ranking of fodder tree species as *posilo* might undergo changes perhaps depending upon the marketing opportunities of individual sites. Because of accessibility to market, farmers in Fikkal and Patle have a large proportion of crossbred milk animals and are supplying more cereal by-products than other sites, particularly Mamling and Fakchamara.

Ranking for *posilopan* at Fikkal was less correlated with other sites perhaps reflecting less dependence on tree fodder at this site and hence less reliance on tree fodder as a protein source in livestock diets. Farmers in Fikkal commonly use oil seed cakes as a protein source whereas it is less commonly utilised in other sites. With the extensive use of cereal by-products, commercial feeds and oil seed cakes, the objective of Fikkal farmers would be to produce more milk from the use of tree fodders rather than increase butterfat content. Since the other sites have less access to oilseed cakes, concentrates and other commercial feeds, their objectives would be an increase in the production of milk and butterfat from the use of tree fodder. Since the market price of the milk is based on butterfat content, tree species that are known to promote only the volume of milk are often undesirable in areas such as Patle and Sindhuwa. *Dudhilo* is considered as *kamposilo* fodder in Patle as it is associated with thin (watery) milk production (Thapa *et al.,* 1997) and decrease in the health of animals. However, *nebharo*, which improves both milk yield and animal health, was ranked more *posilo* in accessible sites (Fikkal, Sindhuwa and Patle) than in less accessible sites (Mamling, Fakchamara and Solma). Perhaps due to this reason, some farmers in Patle and Sindhuwa also maintain buffalo (buffalo milk is known to contain high butterfat) together with cows so as to upgrade the butterfat level in cows' milk for marketing. On the other hand, Mamling and Fakchamara, with less potential for marketing fresh milk prefer production of *ghee* (clarified butter), which has a long shelf-life. As a result, farmers at these sites might have considered ghee promoting tree species as *posilo* fodder.

3.5 Desirable characteristics of tree fodders

A range of attributes of tree fodder and of the trees on which the fodder grows were important in determining desirability of different fodder trees for farmers (Figure 3.13). These attributes were associated not only with the value of fodder for animals but also with management aspects of the tree and the effects of trees on crops.

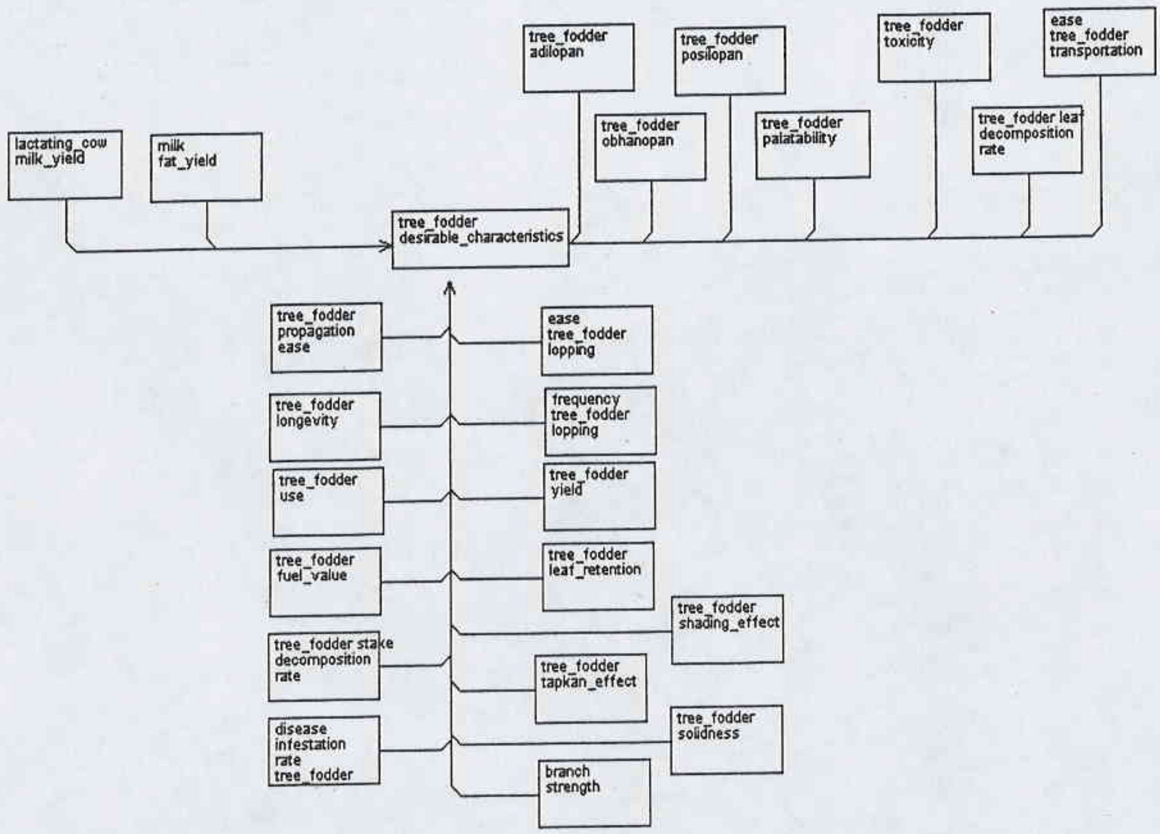

Figure 3.13 Attributes of fodder trees and their fodder affecting their desirability for farmers. The upper part of the figure shows the animal related quality characteristics, yield on the left, fodder attributes on the right and the lower part shows tree management aspects. Nodes represent attributes of system components, arrows show causal influences amongst nodes.

3.5.1 Desirability of tree fodders

The major characteristics identified above as determining desirability of fodder trees were investigated in two hill districts (Terhathum and Dhankuta). Seventy-eight individual farmers (44 male and 34 female) were asked to rank tree species for the characteristics identified as desirable. The results of the questionnaire were compared by age (<45 yrs and >46 yrs, age ranged from 23 to 71), gender, wealth categories (rich and poor) and site (Dhankuta and Tehrathum). The results, showing correlation coefficients of the difference in preference ranking of various desirable factors of tree fodders evaluated in terms of age, sex and wealth categories of farmers and the difference by districts, are presented in Table 3.16.

Table 3.16 Correlation coefficient (r) for ranking of fifteen tree species in terms of various desirable characteristics for two age, gender, wealth and site categories. All are significant at $p>0.05$ except growth by site.

Characteristic	Age	Gender	Wealth	Site
Fodder value	0.960	0.988	0.975	0.828
Fuel value	0.972	0.974	0.988	0.645
Household use	0.972	0.975	0.988	0.674
Easy to propagate	0.951	0.927	0.965	0.635
Growth	0.929	0.937	0.944	0.498
Leaf retentivity	0.963	0.966	0.948	0.794
Easy to lop	0.957	0.941	0.960	0.686
Fodder yield	0.924	0.958	0.975	0.572
Easy to carry	0.955	0.954	0.951	0.639
Tree age	0.941	0.975	0.952	0.579
Shed/*tapkan* effect	0.997	0.997	0.995	0.996
Disease susceptibility	0.966	0.963	0.962	0.764
Manure value	0.926	0.926	0.921	0.616

There was high correlation in ranks for all characteristics of the fifteen species amongst age groups, gender and wealth groups but lower and more variable correlation amongst the two sites indicating more variation in ranking of trees at different sites than amongst genders, age or wealth groups.

The overall preference of tree fodders was derived by averaging the rank scored by farmers for each of the factors considered desirable (above) assuming all characteristics were equally weighted (Table 3.17).

Table 3.17 Mean rank score (SD) for all characteristics given by farmers by site (values are the average of the rank score, higher is better)

Tree species	Dhankuta	Terhathum	Overall
Malbans	12.2 (3.1)	10.1 (4.4)	10.91 (4.08)
Amliso	11.1 (4.2)	9.3 (5.0)	9.96 (4.76)
Badahar	8.7 (4.6)	10.5 (3.7)	9.79 (4.17)
Nebharo	9.9 (4.0)	8.0 (4.2)	8.74 (4.21)
Rai khanyu	9.3 (4.0)	7.9 (3.5)	8.44 (3.75)
Patmiro	6.8 (3.1)	9.2 (3.9)	8.26 (3.81)
Bhimsenpati	8.5 (3.6)	7.2 (4.2)	7.70 (3.99)
Kabro	7.2 (3.1)	8.0 (3.8)	7.69 (3.55)
Khasre khanyu	7.0 (3.0)	8.0 (3.5)	7.60 (3.38)
Dudhilo	6.8 (3.5)	7.9 (4.2)	7.49 (3.97)
Rato siris	7.6 (4.2)	7.4 (4.7)	7.45 (4.53)
Tanki	5.9 (3.6)	8.1 (3.9)	7.28 (3.93)
Painyu	7.2 (5.1)	6.7 (4.2)	6.92 (4.59)
Gogun	6.9 (3.3)	6.2 (3.9)	6.44 (3.67)
Chuletro	5.0 (5.1)	5.6 (4.5)	5.35 (4.76)

Malbans, amliso, badahar, nebharo and *rai khanyu* were the five best tree fodders overall. Some differences were found between the farmers of Dhankuta and Terhathum on overall desirability of tree fodders. *Badahar, tanki* and *patmiro* were the most desirable fodder tree species in Terhathum district, whilst *malbans, nebharo, amliso* and *rai khanyu* were more desirable in Dhankuta district. It was surprising to note that tree species such as *dudhilo, rato siris, tanki, painyu, gogun* and *chuletro,* which are the most abundantly available in the farmlands (Section 2.4.5), were of low preference among farmers.

3.5.2 Reasons for selecting tree species in relation to overall qualities

Reasons for selecting tree species in relation to overall qualities (Table 3.17) were further investigated by interviewing farmers in separate gender groups, each comprising 15 farmers from either Patle, Fakchamara, Parewadin, Mamling, Solma or Fikkal. Summarized results for and against selecting the first four and last four ranked tree fodders are presented in Table 3.18. Summarized results for all other tree species are presented in Appendix 3.4.

Reasons for selecting tree species were a composite of animal factors, properties of fodder trees, their management and socio-cultural reasons. Some tree fodders were preferred because of their high nutritive value (*badahar*) and others for multiple uses (*malbans*). Some trees were preferred because they were easily propagated (*kabro*) and others because they yield more fodder (*nebharo*). Some trees were preferred because the leaves decompose quickly and improve soil fertility (*rato siris*). Some trees were preferred because they have high fuel value (*khasre khanyu).* Some tree species were preferred because shoots can be eaten as vegetable or salad (*tanki* and *kabro)* others were known to retain leaves for longer (*gogun*) and others because of the ceremonial use of their leaves as plates (*nebharo*) and flowers for broom making (*amliso).*

Table 3.18. Reasons for preference of the first four and the last four tree species in overall qualities

Preference order	Tree species	Positive points	Negative points
1	*Malbans*	1. Multiple household uses 2. Palatable and *posilo* to all animals 3. Promotes milk and ghee yield 4. *Obhano* and *adilo*	1. Causes moderate shading effect 2. Roots expose on surface 3. Difficult to harvest fodder
2	*Amliso*	1. Flower is used for making brooms 2. Causes little shading effect 3. Multiple household uses 4. *Posilo* and promotes milk and ghee 5. Longer retention of leaves	1. Poor fuel value (*pocho*) 2. Difficult to harvest (sharp leaf blades/tough skin) 3. Low fodder yield 4. Continuous feeding weakens animals
3	*Badahar*	1. Bears edible fruits 2. *Posilo*, promotes milk and ghee yield 3. Palatable to all animals 4. High timber value	1. Poor fuel value (*pocho*) 2. Causes higher shading effect 3. Difficult to harvest fodder (tall)
4	*Nebharo*	1. Yields more fodder 2. High fuel value (*kharo*) 3. Leaves have ceremonial uses 4. Palatable and *posilo* to all animals	1. Causes high shade and *tapkan* effect 2. Does not grow well on dry soil
12	*Tanki*	1. Shoots can be eaten as salad or vegetable 2. Promotes milk and ghee 3. Palatable and *adilo* to all animals 4. High fuel value (*kharo*)	1. Mature leaves are unpalatable 2. Susceptible to pest infestation
13	*Painyu*	1. Palatable and *posilo* to sheep & goat 2. Higher timber value 3. Dry season fodder	1. Causes problem of *lahumute* (red urine) 2. Unpalatable and *kam-posilo* to cattle & buffaloes
14	*Gogun*	1. Dry season fodder 2. High fodder yield 3. Bears edible fruits 4. Longer retention of leaves	1. Causes moderate shading effect 2. Poor fuel value (*kafalo)* 3. Chiso and not palatable during winter 4. Branches are weak and breakable
15	*Chuletro*	1. Palatable to all animals 2. Leaves decompose quickly and improves fertility of soil 3. Causes little shading effect 4. *Posilo* to sheep & goats	1. Poor fuel value (*pocho)* 2. Branches are weak and breakable 3. Difficult to harvest fodder (thorny) 4. Low fodder yield

3.5.3 Discussion

Mahat *et al.* (1987) reported that farmers with small areas of land were limited in the number of trees that they could tolerate close to their crops because of competition. It can, therefore, be assumed that these differences in the holding of trees between a land-rich and land-poor farmer might influence the knowledge holding between them on the use and preference of tree fodders. However, this study clearly revealed no such differences in the knowledge holding of farmers by wealth status. Similarly, elderly people are often considered more knowledgeable than the young. However, this study revealed no such difference. Findings in this study also contrasted to the earlier report by Joshi (1997) that woman farmers were more knowledgeable about tree fodder than males.

Different harvesting methods of trees also influence farmers' preference for tree fodders. For example, in Patle (Dhankuta district) bamboos are pulled to extract fodder whilst in Damar (Dhankuta district), they are chopped down for fodder and the poles are used for other household functions. In both the eastern and western hills, *badahar* has been reported as a highly preferred fodder tree species (Poudel, 1997) but not many people in Hattikharka VDC (mid hills in Dhankuta district) were using it as fodder because the trees are tall and it was therefore life threatening to harvest them.

Likewise, differences in management practices and land resources, could cause differences in farmer's preference of tree fodders from one area to another. This may explain why *dudhilo* (*Ficus nerrifolia*) and *chuletro* (*Brassiopsis hainla*) were reported as highly preferred fodder species in Dolakha district in the central mid hills (Carter, 1992), contrasting with the opinions of the eastern hill farmers in the present study. Kayastha *et al.* (1998) also reported differences in farmers' preference among five development regions they surveyed. They reported that *badahar* (*Artocarpus lakoocha*) a highly preferred tree species in the east and west was not popular in other regions. Likewise, *gedulo* (also *berulo*) (*Ficus clavata*) popular in the central and western regions was not popular in other regions. Kayastha *et al.* (1998) reported that palatability and nutritive values were the most important criteria used by farmers in their preference rankings. *Malbans* (a bamboo species) is extremely popular in the eastern mid hills, as it is well known to improve nutrition of animals but the perception in certain farm communities in Lamjung, Tanahu and Kaski districts in the west mid hills is that bamboo causes abortion and reduces production in ruminants (Pandey and Neupane, 1995), so limiting its utilization in these districts. Strangely, among farmers of Syangja, neighbouring Kaski district, bamboo fodders are extremely popular as they are thought to promote immediate recovery from illness of animals (Gurung, 2001). Although *dabdabe* (*Garuga pinnata*) has low nutritive value, Sharma (1985) reported that farmers prefer this species because it can be lopped at least twice a year and can be fed to all animal types.

Consistent with present findings, Chapa (1994) reported that *bhimal* (*Grewia oppositifolia*) was popular in Salyan district in the western hills because it increased butterfat content, whilst *khasre khanyu* (*Ficus semicordata var semicordata*) and *khari* (*Celtis australis*) were preferred because of their long leaf retention. Devkota *et al.* (1995) in a study on indigenous management of tree fodders in two villages in Chitwan district have also reported that *posilopan* is not only the reason to adopt a particular species but farmers also considered other factors associated with management and production of trees.

Due to fragmentation of land holdings and declining availability of common forest products farmers are becoming more dependent on their own fodder resources (Mahat *et al.,* 1986). Limitation of cultivable land and restricted access to forest cause farmers to select trees for use on farm that combine multiple benefits for animals, household uses and compatability with crops. Despite their abundance on farmlands *dudhilo, rato siris, tanki, painyu, gogun* and *chuletro* were not preferred species, indicating that farmers are not able to get the trees that they most want on their farm land, creating opportunities for interventions to improve this.

3.6 Factors influencing farmers' tree fodder selection process

During interaction with farmers about the desirability of tree fodders, most farmers strongly combined their preference for fodder with consideration of fuel and manure value of tree fodders. It was assumed, therefore, that while selecting tree species farmers would also take these parameters into account and that they would make a significant contribution to the farmers' tree fodder selection process. Seventy-eight individual farmers (Section 3.2.1) from Dhankuta and Terhathum districts covering Patle and other hamlets near Dhankuta district and Basantapur and Fakchamara in Terhathum district were asked to rank the 15 tree fodders individually on the basis of the quality of fuel and manure values they perceived.

3.6.1 Fuel value of tree fodders

Farmers used three terms when evaluating trees for fuel value, *kharopan* (firewood that burns intensely giving off a lot of heat for a long time), *kafalopan* (quick burning firewood) and *pochopan* (slow burning heavy smoke producing firewood). Seventy-eight farmers (Section 3.2.1) were asked to rank the fifteen tree species in terms of these three fuel categories.

Painyu and *bhimsenpati*, considered as inferior tree species in terms of fodder value, were found to be high quality trees for firewood. More than 85% of the respondents expressed that *khasre khanyu, rai khanyu, badahar, painyu* and *bhimsenpati* were the tree species having the best fuel properties (*kharo*).

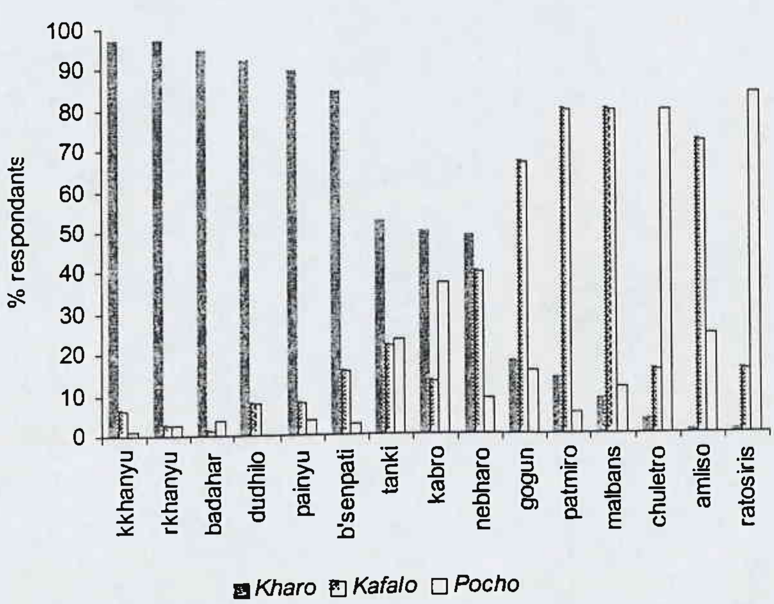

Figure 3.14 Mean ranking of farmers for *kharo, kafalo* and *pochopan* (n=76).

Although *malbans* and *amliso* were highly preferred fodder species, they were reported to be *kafalo,* response ranging from 67 to 80% as were the tree species *rato siris* and *chuletro*, about 80% of the respondents considered them as *pocho* (undesirable firewood). Overall mean ranking of the fifteen different tree species are presented in Figure 3.14.

3.6.2 Manure value of tree fodders

Farmers were often found to relate the quality of tree fodders with their effect on the quality of dung an animal produces. Some farmers also reported that the dung quality was an indicator of the health of the animals. They reported that both 'very hard dung' associated with constipation, and 'watery or loose dung' are troublesome for management and undesirable for utilization of manure. The farmers distinguished manure quality of tree fodders in three distinct categories, which were evaluated separately in a group of 20 farmers comprising men and women in two hamlets within Dhankuta district. Characteristics for each category of manure were as follows:

1. *tikau mal*: this signifies *malilo* (fertile) and *tikau* (long lasting) manure, which was also distinguished by its dark brown colour. They said that this kind of manure was easy to transport and apply. Also, the manure would decompose slowly and could sustain the next crop.

2. *kam tikau mal*: is the opposite of *tikaumal* in terms of rapid decomposition but is also fertile (*malilo*). The manure is loose, making it labour intensive to apply and difficult to transport. Farmers reported that this type of manure supports one crop only and application of a lot of manure is required to support subsequent crops.

3. *rukho mal*: was solid dung that was bulky and friable. Nutrients from this manure were either not available or were quickly lost. *Rukho mal* does not easily blend with soil and a large portion of it would be wasted. A very large amount of this type of manure is required to support the existing crops.

This group of twenty farmers were able to classify the 15 different tree species into the three main types of manure that resulted from their feeding (Table 3.23).

Table 3.23 Three categories of the fifteen tree fodders in terms of manure quality. Categories 1, 2 and 3 are *tikau mal*, *kamtikau mal* and *rukho mal* respectively. They were categorized by a group of 20 farmers.

Tree species	Category	Characteristics expressed by farmers
Badahar	1	Dark greenish solid dung, slowly decomposable, amount of manure for next crop is reduced.
Bhimsenpati	1	Dark-greenish solid dung, slowly decomposable, has residual effect to next crop.
Gogun	1	Greenish brown solid dung colour, slowly decomposable, has residual effect to next crop.
Rai khanyu	1	Reddish brown solid dung, slowly decomposable, can support the productivity of next crop
Tanki	1	Greenish solid dung, slowly decomposable, sustains next crop i.e. amount of manure for next crop is reduced.
Rato siris	1	Greenish solid dung, speeds rotting of other roughages/stakes, improves physical quality of soil, '*tikau'* and slowly decomposable.
Khasre khanyu	1	Dark-brown solid dung, slowly decomposable, has residual effect for next crop.
Patmiro	2	Greenish loose dung colour, rapidly decomposable
Nebharo	2	Greenish solid dung, easily decomposable, less residual effect to next crop.
Dudhilo	2	Loose dung, collection difficulty, rapidly decomposable, mixing difficulty with soil.
Kimbu	2	Light green loose dung, rapidly decomposable and nutrients quickly lost.
Kabro	2	Greenish loose dung, rapidly decomposed and nutrients quickly lost.
Chuletro	2	Greenish loose dung, *kamtikau*
*Painyu**	2	No experience on large ruminants.
Amliso	3	Light green dung colour, mucus in dung, decomposable and is '*kamtikau'*.
Malbans	3	Light greenish solid dung but dry/friable and bulky, requires large application of manure. The manure is not effective to support the productivity of crops.

*only to goats, since all the participants have not experienced feeding *painyu* to large ruminants

3.6.2.1 Effects of feeding different fodder tree species on the quality of manure produced by animals

The manure typology described by farmers was examined in interviews with 78 farmers (Section 3.2.1). These farmers were asked individually to evaluate the effects of feeding different fodder tree species on the quality of manure produced by animals and the subsequent effect of manure on soil fertility. Each farmer was asked to rank the tree species on the basis of the characteristics such as the manure quality of tree species *tikaupan* of manure (*tikau/kamtikau*), leaf decomposition (slow or fast), dung solidness (solid or loose), dung heaviness (heavy or light) and transportation (easy or difficult).

The manure quality associated with tree fodders and their characteristics varied with tree species. *Malbans* and *amliso* were the most preferred tree species as fodder, however, they were associated with low manure quality as their leaves decompose slowly which is undesirable and the manure is only moderately *tikau*. The other most popular fodder species, *badahar*, however, was desirable in terms of the manure characteristics that it was associated with (Table 3.24). In general, the least preferred tree species were reported to be *kam tikau* and heavy and difficult to transport.

Table 3.24. Proportion (%) of farmers agreeing that various attributes of manure result from feeding different fodder tree species (n = 78)

Tree species	Ease of transport		Dung heaviness		Dung solidness		Leaf decomposition		*Tikaupan*	
	Difficult	Easy	Heavy	Light	Solid	Loose	Fast	Slow	*tikau*	*kamtikau*
Malbans	11	87	31	68	91	5	1	99	50	50
Amliso	6	94	42	56	92	5	1	99	42	58
Badahar	9	91	49	50	92	5	40	60	91	9
Nebharo	68	31	58	41	15	81	91	9	69	31
Rai khanyu	19	79	31	68	81	15	28	72	82	18
Patmiro	60	38	63	36	32	64	90	10	54	46
Bhimsenpati	22	78	27	72	78	19	96	4	53	47
Kabro	67	32	59	40	28	68	65	35	63	37
Khasre khanyu	10	88	38	60	91	5	18	82	81	19
Dudhilo	94	5	63	36	3	94	69	31	26	74
Rato siris	51	46	55	42	29	65	94	6	69	31
Tanki	9	90	40	59	94	3	19	81	91	9
Painyu	51	38	46	44	35	55	22	78	19	77
Gogun	19	79	46	53	78	18	11	88	72	28
Chuletro	69	29	76	23	28	68	85	15	17	83

3.6.3 Discussion

Farmers make complex decisions about which trees to retain on their farm land directed by various socio-cultural, animal and management factors (Devkota *et al.*, 1995). Local people have not only retained trees that have high nutritive value but also other tree species, showing that they consider multiple factors in their selection process.

Use of trees for fuelwood may be an important secondary role for fodder trees on farm land. Although not clearly defined, Carter (1994) reported a similar grading system for fuel quality of wood from fodder trees in the central mid hills of Nepal as has been reported here in the East, indicating the generality of this feature across the mid-hills. Although biogas has recently been introduced in some communities in the eastern mid hills, trees are an important source of fuel in the rural life in the hills of Nepal (Gilmour and Nurse, 1991). Where fuel wood is in short supply, firewood derived from the stakes of the fodder trees is still the only means for local people to cook their own food and the *khole*[12] that they feed to animals. Fodder trees are lopped and the cuttings carried to stall fed animals whilst the leftover branches are used as firewood. In the animal feeding experiments (Chapter 5), it was observed that large animals refused lopped branches of trees greater than about 2.5 cm in circumference. However, the circumferences of the chopped branches varied from about 3.5 cm to about 8 cm for *Ficus* species, a substantial wastage if we assume only fodder uses. Clearly decisions about which fodder trees to retain may be influenced by their fuel quality.

A major reason for keeping livestock in the mid-hills is to provide dung as a fertiliser for crop land. Farmers distinguish the quality of dung by means of its compactness and decomposability and recognise how feeding different tree fodders results in dung of different quality. Thus, manure quality is an important factor that farmers consider while selecting tree species to retain on farm land. Though the use of inorganic fertilizer is increasing in areas with accessibility to markets, farmers still rely heavily on organic fertilizer to maintain soil fertility because chemical fertilizers are costly and their quality, in Nepal, is often unreliable (Anderson, 2001). Both trees and grasses are often mixed with crop residues for fodder and bedding in animal stalls. When the leftover feeds and bedding materials are composted with dung, they become the principal organic fertilizer used in crop lands in the traditional farming system in the hills. Yields of crops grown in the major cropping sequences in the hills of Nepal are sustained at higher levels by the application of manure, rather than chemical fertilizer alone (Sherchan *et al.,* 1999).

Some lowly ranked tree species in terms of feeding value such as *bhimsenpati* and *gogun* (Table 3.11) were associated with high quality manure (*tikau mal*) whilst some

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[12] *Khole* is made from a mixture of maize flour, rice bran, oilseed cake, vegetable wastes, kitchen swills and salt in a large volume of water.

highly rated fodder species such as *malbans* and *amliso* were considered inferior or undesirable in terms of manure quality. However, *badahar*, *rai khanyu* and *rato siris*, were highly rated for both fodder and manure. There are some interesting trade-offs apparent here. Slowly decomposable manure (*tikau mal*) while advantageous to sustain multiple cropping, is associated with fodders with high phenolic content that also have low digestibility and are not good providers of available nutrients to animals. These trade-offs are reflected in the way that market-orientated farmers in accessible areas are able to choose tree fodder to maximise animal production whilst subsistence orientated farmers in remote areas tend to modify their selection of tree fodder to ensure year round soil fertility (Conlin and Falk, 1979).

3.7 Strategies to cope with dry season fodder shortage

With the advancing dry season and decrease in green fodder resources, farmers become active in planning strategies to feed their animals.

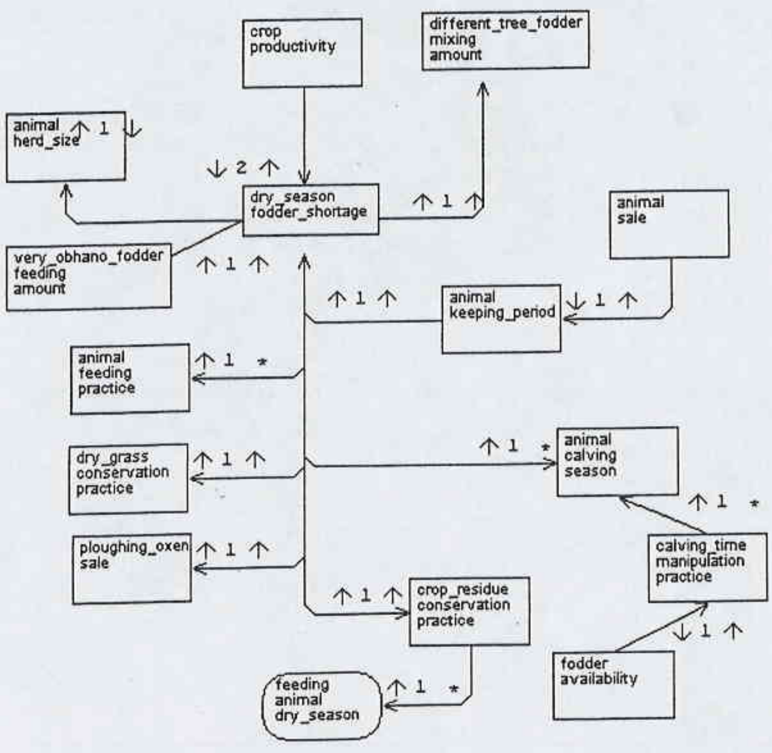


Figure 3.15 Systematic representation of farmers' causal knowledge about various strategies used to cope with dry season fodder shortage. Knowledge about conservation and feeding practices is shown on the left and bottom of the diagram and knowledge about animal management strategies on the right. Symbols as in legend to Figures 3.1

Because of their familiarity with and extent of dependence on trees, farmers make decisions about individual trees considering their seasonality, palatability and impact on animal and crop productivity. Alteration of feeding systems, conservation of fodder and changes in management of animals were the main strategies reported by farmers for coping with dry season fodder shortage. A systematic representation of farmers' causal knowledge of how they cope with dry season fodder shortage is presented in Figure 3.15

3.7.1 Management of animals during the dry season

When natural growth of forage slows, farmers manage and maintain their animals, trees and croplands in the best way they can within the limit of their resources and farm labour. Farmers explained various strategies to adapt and cope with dry season fodder shortages. Most farmers in the eastern middle hills feed their animals in stalls for most of the year. However, in some cases as soon as the field-crops are harvested, the fields are opened to livestock to feed on agricultural residues and weeds. The animals are often kept in the field in temporary stalls and shifted from one field to another to manure the cropland. This practice is well established in almost all households in the eastern mid hills.

3.7.1.1 Sale and purchase of animals

As the dry season progresses, most farmers in the mid hills manage their fodder supply by manipulating farm animal herd size. This is done by deciding which animals to cull and which animals to retain. More than 50% of farmers reported that they sell oxen after major farm activities are completed, ensuring that older and heavier oxen are generally culled before the younger ones. They also reported that sterile or unproductive cows are also disposed of in the same way but the percentage of farmers who reported this was much higher (Table 3.25). Less than 50% of farmers reported that they purchased young animals to replace the animals that were sold or disposed of. These activities were more common in Patle and Fakchamara than in Basantapur (Figure 3.16).

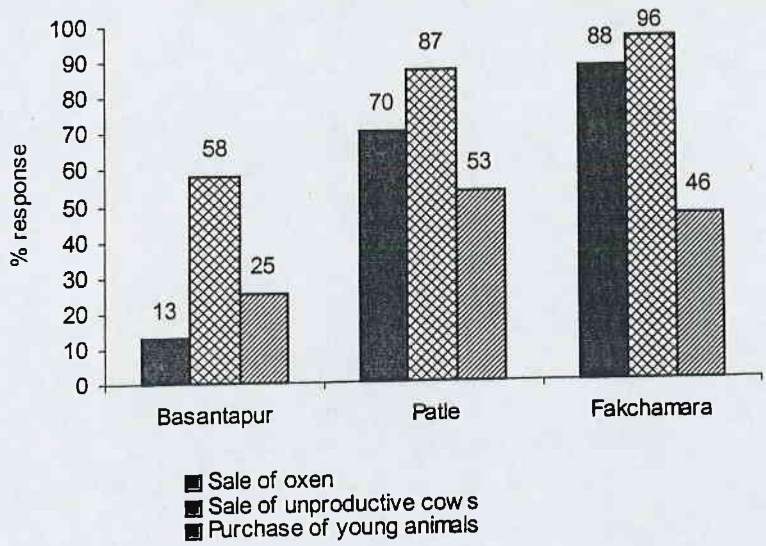


Figure 3.16 Percentage of farmers engaged in herd management activities at Basantapur (n=24), Patle (n=30) and Fakchamara (n=24)

Sale of oxen and unproductive cows was more common among rich farmers than poor farmers (Table 3.25).

Table 3.25 Percentage of farmers engaged in herd management activities by wealth category (rich, n=40 and poor n=38)

Herd management	Rich (%)	Poor (%)	Overall
Sale of oxen	65	50	58
Sale of unproductive cows	85	76	81
Purchase of young animals	43	42	42

3.7.1.2 Manipulation of breeding

During the interaction with farmers it was understood that the farmers manipulate breeding of animals to coincide with the seasonal availability of wet season forages. They reported that the animals are crossed in such a way that the cows should calve at the beginning of the wet season. It was found that the practice of manipulation of breeding was most common in Fakchamara and less common in Basantapur (Figure 3.17). Only a few farmers in Patle reported that they actually follow this practice as they cross the cows whenever they come on heat (oestrous). Slightly more rich farmers than poor farmers (55% vs 45%) manipulated the breeding time of animals.

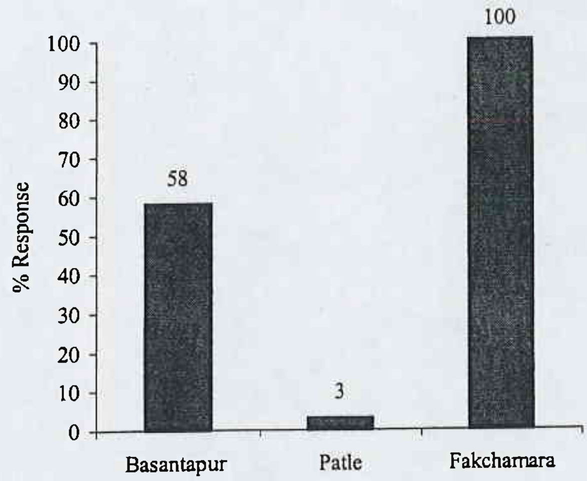


Figure 3.17 Percentage of respondents at Basantapur, Patle and Fakchamara reporting manipulation of breeding time.

3.7.1.3 Migration of animals

Local farmers reported that during the fodder shortage period some households distribute their animals to their neighbours who have more fodder resources and more cropland. This is done in exchange for manure and animal feeding in a mutually agreed arrangement between two farmers that we will denote as farmer (a) and farmer (b) (Figure 3.18).

Farmer (a) usually has a relatively high number of animals relative to their land area and not enough fodder, while the opposite is true for farmer (b). Mostly unproductive and dry animals of farmer (a) are moved to croplands of farmer (b). It is the responsibility of farmer (b) to take care of the animals of farmer (a) while they stay with him.

Farmer (b) usually houses them under a mobile shed with bedding of weeds and unpalatable plants. A schematic diagram of management of animals by farmers during the dry season is shown in Figure 3.18.

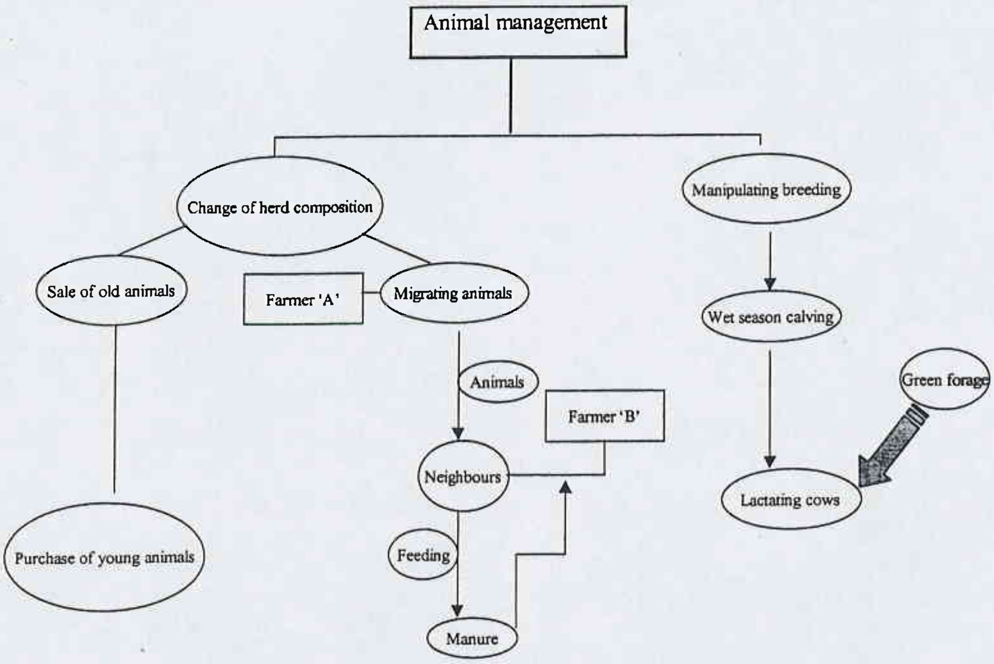


Figure 3.18. Schematic diagram of management of animals during the dry season

Overall, roughly half of the farmers reported that their animals were moved to other farms with more at Patle and fewer in Fakchamara (Figure 3.19). Rich farmers were practising this much more than poor farmers (73% vs 37%).

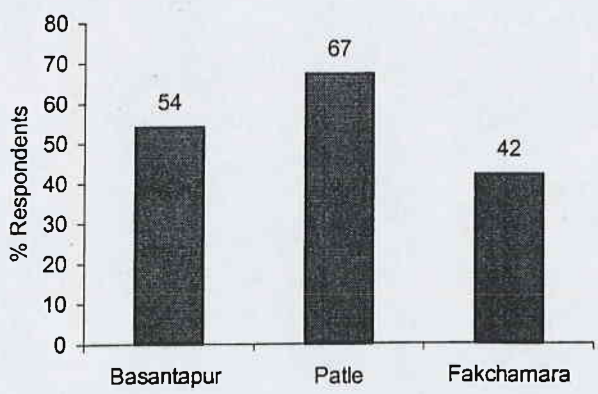


Figure 3.19 Percentage of respondents at Basantapur, Patle and Fakchamara migrating animals in the dry season

3.7.2 Feeding management

3.7.2.1 Feeding according to productivity of animals

Farmers maintained an inventory of their animals and planned feed supply based on the physiological and productive status of their animals. As the quantity of feed required to ensure adequate nutrition for all animals could not be met from the existing trees during the dry season, farmers reported that they adopted a feeding management strategy. Farmers ensured supply of their best fodders (*posilo*) in terms of milk (*dudh aune*) and butterfat promotion (*ghieu lagne*) to their highest priority animals. They reported that they also supplied additional *khole* (about 1.5 times more than the normal amount in other seasons) to lactating animals during the dry season to compensate for fodder deficiency and to maintain the milk productivity of cows and growth of young calves. Likewise, growing animals were also given *posilo* fodder to ensure rapid growth whilst *adilo* fodders were fed to draught animals to satisfy their appetite (Table 3.26).

Table 3.26. Utilisation (%) of *posilo* and *adilo* tree fodders for growing, lactating and working animals reported by farmers (n=78)

Animal type	*Posilo*	*Adilo*	*Both Posilo &Adilo*	Any
Growing	72.73	24.24	1.52	1.52
Lactating	89.39	9.09	1.52	0
Working	18.18	77.27	4.55	0

Farmers reported that oxen were also given *posilo* fodder when working but when idle, the fodder quality offered would be similar to that given to dry cows. They also reported that oxen and unproductive animals were expected to forage, scavenge or were given less desirable fodder. The choice of *posilo* fodder for productive animals was explained simply on the basis of anticipated returns in terms of cash income from the sale of animals, milk or butterfat. While a substantial number of poor farmers (18%) were feeding *adilo* fodder to the lactating animals, no rich farmers did but more rich than poor farmers reported feeding *posilo* fodder to lactating and draught animals (Table 3.27).

Table 3.27. Utilisation of *posilo* and *adilo* tree fodders (%) for growing, lactating and working animals reported by rich and poor farmers (n=78)

Wealth status	Animal activity	*Posilo*	*Adilo*	*Both posilo & adilo*	Any
Rich	Growing	69.7	27.3	0.0	3.0
	Lactating	97.0	0.0	3.0	0.0
	Working	24.2	72.7	3.0	0.0
Poor	Growing	75.8	21.2	3.0	0.0
	Lactating	81.8	18.2	0.0	0.0
	Working	12.1	81.8	6.1	0.0

Apart from tree fodders, farmers reported that they used grasses and weeds for fodder, which are generally available growing wild around riverbanks, gullies and wastelands (Section 2.4.1.3). Although quantitatively small, they are an important source of green material for *khole* preparation. Some grass species such as *gagleto* (botanical name unknown) were reported to be available throughout the year as an ingredient for *khole* for both ruminants and non-ruminants (pigs).

3.7.2.2 Utilization of low palatability fodder resources

Normally stalled animals were fed three to four times a day, but this frequency was reported to increase during the dry season. Farmers reported that they tried their best to give *ramro* (good) fodder at least once during the day. The fodder that was given at night generally consisted of *sukkha ghans* (rice straw), green forages or tree fodders and the less palatable fodders that are often rejected by animals during the day. Since animals will not eat less palatable fodder by itself, small quantities of palatable fodder was put on top of the unpalatable fodders in the feeding crates. The placing of small amounts of palatable fodder on top of the unpalatable fodder could be repeated several times during the night. The farmers' reasoning was that with intake of palatable fodder, animals also eat some unpalatable fodder and if the animals have not satisfied their appetite in a day's grazing, they are forced to eat unpalatable portions of feed in the night. The use of tree species was reported to vary from one feeding period to another so that if one species was fed in the morning a different tree species would be fed later in the day. More than 60% of farmers reported that they utilized less palatable fodder by frequent feeding of small portions of it in conjunction with more palatable fodders

(Table 3.28). This practice has also been widely followed in the mid western region of Nepal (Mrs S Acharya, *pers. Comm.*) and in Syangja district in the mid hills in west Nepal (Gurung, 2001).

Analysis by gender and wealth categories showed no marked differences on utilization of less palatable fodders, although the number of poor farmers reporting that they supply low palatable fodder at night was slightly higher than the number of rich farmers.

Table 3.28 Response (%) of farmers by gender and wealth status on utilization of low quality fodder during the dry season

Feed planning	Gender		Wealth		Overall
	Male	Female	Rich	Poor	
Feed less palatable fodder at night	64	62	53	74	63
Increase frequency of feeding less palatable fodder	82	88	90	79	85

These practices were prevalent at all study sites. However, in Fakchamara increased frequency of feeding less palatable fodder was more common than the practice of feeding low palatable fodder at night (Table 3.29).

Table 3.29. Response (%) of farmers at Basantapur (n=24), Patle (n=30) and Fakchamara (n=24) on feed planning during the dry season

Feed planning	Basantapur	Patle	Fakchamara
Feed less palatable fodder at night	88	60	42
Increase frequency of less palatable fodder	83	73	100

3.7.2.3 Practice of mixing different tree fodders

Livestock are fed principally on three types of roughages: grasses, crop residues and tree fodder. The proportion of each varied seasonally. In the wet season grasses were the main source of feed, whilst crop residues and tree fodder were the main feed types in the dry season. With the approach of the dry season, to economise the feed use, farmers reported that they fed mixtures of different fodder types with different quality attributes. A mixture of both *ramro* (palatable and nutritious) and *naramro* (less palatable and less nutritious) fodder types was reported to be the most common practice of mixing. Mixing of different fodders and farmers' knowledge on causes and effects on management and animal factors are summarised in a causal diagram (Figure 3.20).

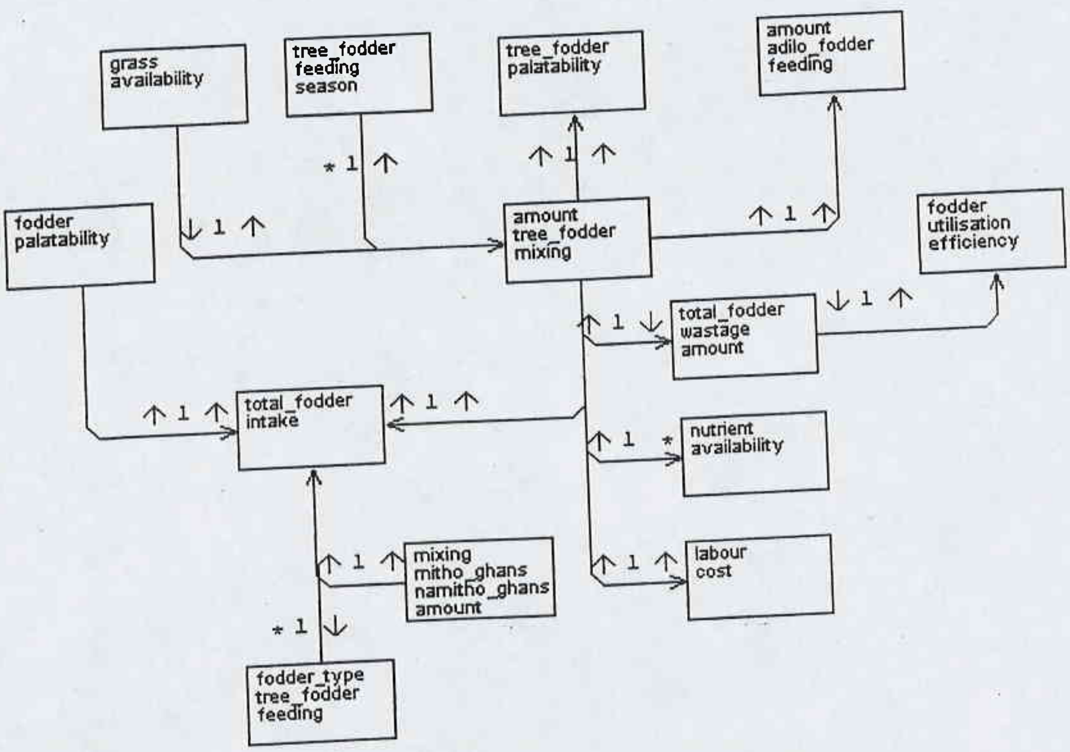


Figure 3.20 Systematic representation of the reasons for farmers' fodder mixing practices and their consequences. Symbols as in legend to Figures 3.1

To ensure that animals were well fed, tree species were normally changed from morning to evening in three different feeding schedules comprising palatable/unpalatable or *posilo/kamposilo* fodder types. Decisions on the quality of tree species for subsequent feeding were reported to be chiefly determined by what the previous fodder intake had been so that a more palatable fodder would be supplied if the intake of the previously supplied fodder had been low. For example, the feeding schedule of tree fodders to supplement rice straw based feeds normally practised by Mr Amar B. Raya, (age 49 yrs, Patle) was:

06:30 *malbans*), → 12:00 *amliso*) → 16:00 *rai khanyu*.

According to Komal P Bhandary (age 72 yrs) also from Patle, mixing a small amount of *chiso-kamposilo* fodder such as *sanopate dudhilo* or *painyu* with palatable or *ramro ghans* such as *malbans* or *badahar* led to efficient utilization of less palatable fodders and at the same time, this sort of combination improved the health of animals.

Supplementing very *obhano* fodder such as rice straw with green material was a common practice in all the study sites but less than a third of farmers mixed different types of green material comprising more rich farmers (42%) than poor farmers (19%).

Almost all farmers interviewed reported that when different feeds were mixed, the total feed intake would be increased and the overall fodder quality would be higher. Most farmers reported that mixing was done to control the hunger of animals and to economize fodder use through improving utilization of less palatable or unpalatable fodder species. They also reported that they ensure giving good quality fodder for at least one feeding time per day.

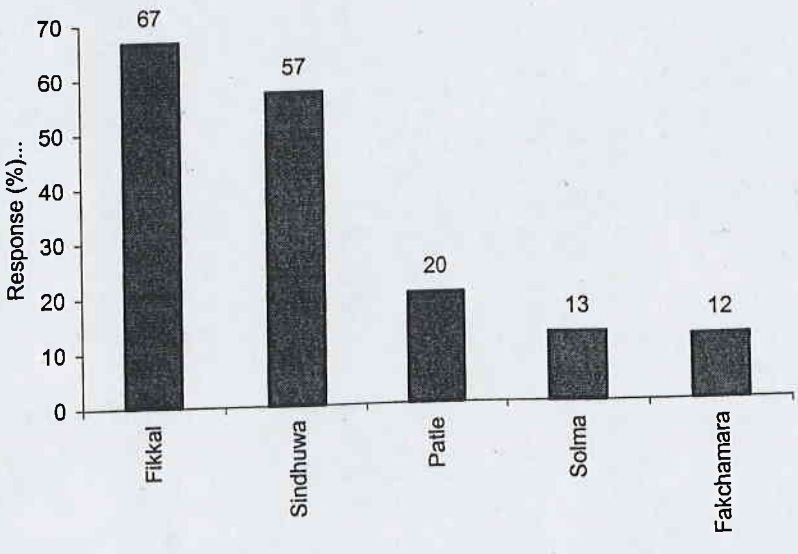


Figure 3.21 Use of tree fodder mixing practices by farmers at five different sites. Based on the interview with farmers (n=66) given in Table 3.4 above.

The practice of mixing different fodder appeared to be closely related to market accessibility (Figure 3.21). Fikkal, Sindhuwa and Patle, being the market accessible sites with more commercial interventions had larger number of farmers reporting mixing practices than the farmers of either Solma or Fakchamara, which had less accessibility to market and low commercial interventions.

3.7.2.4 Conservation of fodder for dry season feeding

Crop residues derived from *khet* or *bari* land such as rice straw, millet straw, maize sheaths, maize tops, maize stovers and haulms of oilseeds form an important feed source for the animals in the hills, particularly for dry season feeding. Some farmers reported that they allowed forages in marginal lands to mature (when there was surplus) for animal feeding or thatching a house or cowshed. *Khar* (thatching grass) varieties such as *lamokharuki* (botanical name unknown), *sano kharuki* (botanical name unknown), *bankosi* (botanical name unknown) and *banso* (*Eragostis tennella*) were local varieties usually conserved for dry season feeding. Depending upon their availability, they were allowed to mature in the field, then cut and often stored in an attic or open place under the roof of animal sheds.

Almost all farmers reported that they stored crop residues for feeding during the dry season (Table 3.30). Rice straw was the most important crop residue but was not available in large enough quantities for all farmers. Almost all farmers reported that they purchased rice straw for feeding, particularly during the dry season. Analysis of data by site revealed some variation in conservation practices among sites. Conservation of dry grass was a common practice in Fakchamara but not in Patle and Basantapur (Table 3.30).

Table 3.30. Response of farmers (%) about conservation of dry roughages by site and wealth categories

Dry roughage type	Site			Wealth		Overall
	Basantapur	Patle	Fakchamara	Rich	Poor	
Storage of crop residues	100	100	83	95	95	95
Purchase of rice straw	79	100	100	88	100	94
Conservation of grass *(khar)*	25	0	63	28	26	27

3.7.2.5 Fodder tree species with long leaf retention

Local people reported that there were some tree species that retained their leaves for longer than most into the dry season so that green leaves were available during the critical period of fodder shortage. Long leaf retention was a desirable characteristics reported by farmers when evaluating fodder trees. The longer leaf retaining tree species reported were *gogun*, *khasre khanyu*, *nebharo*, *patmiro* and *rai khanyu*. Farmers also reported that the retention of leaves was dependent on the degree of exposure to sun and wind and whether or not the plant was growing in fertile and moist soil conditions. Trees maintained on fertile and moist land were thought to retain leaves for longer than trees growing in dry or poor soil. They reported that trees growing in sunny and dry areas absorb less water, making the soil infertile and as a result tree leaves are quickly lost. They also reported that the palatability of the tree leaves under such conditions would be poor compared with the leaves of shaded trees.

Farmers reported that they plan tree fodder lopping regimes to suit their fodder demands with all available fodder resources they have on their farmland. They reported that based on the nature of leaf retention, they plan tree lopping according to the shedding time of each species. Although there were some farmers who reported that they lop fodder trees at any time they wish not necessarily taking into account whether or not the plant was receiving solar radiation, usually the trees in sunny and windy locations were lopped first and trees in shady sites were lopped later. An observation study conducted by Subba (2002) in Patle and Pakhribas revealed that 37% of *patmiro* and 79% of *gogun* and *rai khanyu* leaves were retained until the end of Jestha (May/June). Farmers in general were found to reserve fodder from these trees for feeding for later in the dry season when other fodder was unavailable. They planned lopping regimes to suit their fodder needs from available fodder resources they have in their farmland and make efforts so as to make continuous supply of fodder.

3.7.3 Discussion

Carter (1992) reported that most trees on private land in Suri and Melung villages Dolakha district in the Central mid hills of Nepal were of high fodder value and that private land was the major source of highly valued species of tree fodders. In the present study it was evident that many of the fodder trees retained on farm land were of low fodder quality and appeared to be maintained for other reasons such as their use as fuelwood. As the farmers maintain several species of animals, tree species which are *kamposilo* and unpalatable to large ruminants, may be *posilo* and palatable to small ruminants (sheep and goats). All animals are housed together in the same shed, and nutritious and palatable fodder supplied to the lactating cows may also be given occasionally to the other animals to avoid them being attracted to the cows' food. The few farmers reporting that they provided *posilo* fodder to animals other than lactating animals could reflect this. In the hills, the oxen were reported to receive diets depended on their activity. On work days, oxen were generally supplied with *adilo* fodders (derived from a mixture of crop residues and tree fodders followed by dry *khole* (consisting of salt and local concentrates without addition of water). However, immediately after work, both *posilo* and *obhano* types of fodder were supplied with *ramro khole*[13]. Eighteen percent of the farmers, who responded that they practised feeding *posilo* fodder to oxen might be those who considered feeding *posilo* fodder immediately after work.

Longer leaf retention

The critical period of fodder shortage according to the local farmers was for three months from mid February to mid May. The farmers' knowledge system appeared to be crucial during this critical period in making decisions about the management and use of available fodder resources. Farmers make efforts to provide a continuous fodder supply and plan tree fodder lopping regimes accordingly. Based on the nature of leaf retentiveness, farmers lopped early shedders earlier and the later shedders later. Farmers

[13] A ramro *khole* generally constitutes a mixture of rice bran or maize flour or maize grits, mustard seed cake, vegetable wastes, and vegetable tops.

often preferred those fodder species that could supply green fodder during the dry season of the year. Carter (1992) reported similar findings for farmers in Dolakha district in the central mid hills. Perhaps the existence of ranges of tree species in the farmland may be related to their times of leaf shedding and not necessarily to their *posilopan* and *obhanopan* attributes. Carter (1992) also reported that farmers often prefer those fodder tree species that could supply green fodder during the dry season of the year. Some tree species are early shedders (*rato siris* or *badahar*) and others are late shedders for example, *gogun* and *nebharo*. *Gogun* is considered as *naramro* or *chiso* fodder and *khasre khanyu* as not very palatable whilst *nebharo*, due to its large canopy and broader leaves has a negative effect on crop productivity and *dudhilo* is a below average quality tree fodder. Their maintenance in the farmland may be because they retain leaves for a longer period and become available for feeding when there is paucity of green fodder. Although *khasre khanyu* leaves are generally coarse and of low palatability, young leaves are palatable and *posilo* during the most critical period of fodder shortage.

Feed utilization according to animal type

The diminishing fodder resources of the dry season dominate farmers' decisions about feeding and management of fodder. Farmers' decisions about tree fodder selection may also be related to the intended outputs, whether for milk or butterfat or both. Productive animals were provided good fodder whilst unproductive animals were provided with poor fodder. This practice of feeding tree species according to the productivity of animals is also prevalent in other parts of the country: Carter (1992), Dolakha district, central middle hills; Mrs S. Acharya (*pers. Comm.*), Arghakhanchi district and Poudel (1997), Kaski district, western mid hills. There is a suggestion that *posilo* fodder with relatively more *chiso* types of fodder is offered to animals for increased milk production whilst *posilo* fodder with relatively more *obhanopan* fodders is offered for increased butterfat production. Accessibility to marketing opportunities has a direct influence on this. Farmers in areas with market accessibility are more interested in milk production whilst in market inaccessible areas more importance is attached to butterfat production (Section 2.2.1). As a result lactating animals are better cared for and are given more *posilo* fodder compared with dry cows or oxen. This practice is also prevalent in the central mid hills (Gilmour, 1997) and western hills (Gurung, 2001). Allowing the unproductive animals to graze and scavenge might not only be associated with coping with fodder deficiency but also to maintain the physical condition of draught animals. Gilmour (1997) reported that open grazing is necessary for oxen in order to maintain their muscle tone for draught work.

Mixing of different fodder types

Shortage of tree fodders during the dry season is well understood as a constraint to increasing livestock production in the mid hills of Nepal (Singh, 2000). Animals are fed mixtures of various fodders available in a household, which is also a common practice in the Syangja district (Gurung 2001) and Parbat district (Rusten and Gold, 1991) in the western mid hills of Nepal. This practice of feeding a mixture of different feeds was reported to improve intake and efficiency of feed utilisation of available fodder resources. Carter (1992) reported that the farmers in Dolakha district feed a mixture of *chiso* and *obhano* fodder, as this is said to be optimal for animal health and nutrition. Rusten and Gold (1991) also reported that *chiso* fodders, considered to be of poor quality were usually mixed with *obhano* fodders to avoid the risk of animals choking.

Mr Komal P Bhandary (age 72 years, Patle) often mixes *ramro* (palatable) and *naramro* (unpalatable) fodders as he thought that sole feeding of tree fodder is harmful to animals, causing weakness and cessation of milk yield. Similarly Salbote village[14] farmers reported that feeding a mixture of different fodder species would improve feed intake and productivity of animals. They argued that feeding only *chiso* fodder might improve volume of milk yield but this would make the animals hungrier and the need to supply additional fodder could be a problem. Likewise, there would be a drop in milk production if only *obhano* or *adilo* fodder was fed to the animals. Thapa *et al.* (1997) also reported the adverse impacts on animals stated by Solma farmers when *chiso* fodder constituted a sole feed. Thapa (1994) reported that farmers avoid certain tree species, such as *painyu*, which are known to be deleterious to animals. It appears that

[14] *Salbote* is a low ward (at altitude <850 m) within the Pakhribas VDC in Dhankuta district, inhabited by Rai community. Cattle are maintained mainly for calves as a source of cash income, with no tradition of selling milk or milk products but occasionally butterfat is sold in the local market.

feeding a mixture of fodders would not only economise fodder use but also protect the animals from detrimental effects to their health and productivity as a consequence of sole feeding reported by Thapa (1994) and to improve the voluntary intake of fodder (Joshi 1997). Devendra (1989) also reported that farmers in a global context practice feeding a mixture of different feeds to overcome any adverse effects on animals of any individual fodders. Perhaps the process of mixing not only extends the choice of feeds available but also dilutes and reduces problems of palatability and the deleterious effects from sole feeding. Other reasons for mixing different qualities of tree fodders might be an attempt to regulate rates of decomposition and nutrient release in the animal system or production of composite manure with sustainable quality, which is referred to as '*tikau mal'*. Farmers' decisions to select different tree fodders for mixing would be dependent on household circumstances and availability of labour. Depending upon the physiological stages of animals and priorities to these animals, farmers ensure that good quality fodder is provided for at least one feeding time per day. However, their choice and strategy would be determined by the availability of good quality fodder towards the end of the season when other feed sources are diminishing.

The practice of fodder mixing appeared to be closely related to market accessibility. Despite accessibility to market, the reasons why only a few people in Patle mix different species of trees became clear from the statements of Padam B. Bhandary, (age 47 yrs, Patle):

> *Mixing of different tree fodders is not generally followed except in some difficult situations. This is because of unavailability of various species of trees or other green forage crops in my farmland.*
>
> *Also the tree species I own are not very different in terms of obhano and posilo quality attributes. Had there been sufficient tree species, I would have been feeding these tree species selectively.*

The low number of farmers (30%) practising mixing different tree species was reported to be due to lack of varieties of tree species available in the farmland owned. However, farmers who did have a number of tree species on their land were not always found to be mixing fodders. Interviews with these farmers revealed that they do not do it because of lack of labour. Therefore, it appears that the primary objectives of a resource poor farmer would appear to be filling the animals with fodder rather than feeding selectively to increase productivity.

Management of animals

In response to feed shortages, most farmers manipulated breeding time of their animals to coincide with seasonal availability of fodders. Anon (1990) also reported that the cattle and buffalo in Nepal in general calve during the wet season. According to Conlin and Falk (1979), animal holdings of rich farmers are generally higher than those of poor farmers. This may be the reason why more rich farmers than poor farmers manipulate breeding time.

Migration of animals from one farm to another and to neighbours for exchange of manure and animal fodder was reported to be an important strategy followed by farmers. However, this practice varied from place to place depending upon the fodder and animal holding of each household.

Khadka and Gibbon (1988) reported that more than 50% of farm income in the eastern mid hills was derived from animals and animal products. They are an extremely important source of income to farmers (Conlin and Falk, 1979). Animal trade operates at the start of the dry season (October), which fortunately coincides with the Nepalese festival *Dashain* when a large number of animals are sacrificed. Since Hindu law forbids slaughtering of cattle, caravans of unproductive cattle can be witnessed being driven from the mid hills via the *terai* targeted for Indian and Bangladeshi markets.

Conservation of fodder

Low quality fodders like straw and stover are the only means of survival of animals in many areas during the dry season. A way to mitigate this problem would be either to improve the quality of these conventional feeds or to conserve excess forage during the wet season to feed to the livestock when there is deficit. Some farmers practise conserving seasonal forages in the form of hay, which is a traditional practice in the high hills and mountains of Nepal (Singh 2000; Banstola and Shrestha, 2000). Singh (2000) also reported that hay prepared from stylo, molasses and local grasses in early October was highly palatable and nutritious to animals. However, he reported that the rate of adoption by farmers was insignificant, although farmers in the study sites reported some forms of conservation practice. However, lack of land limited most farmers in the conservation of dry grasses. The farmers who had been conserving dry grasses from certain local species did so primarily with the aim of using them for thatching. Hence the quality of these grasses in terms of feeding value could be expected to be low. Balaraman (1996) reported the possibility of making hay from tree leaves such as *nebharo* in Indian hill districts similar to the mid hills of Nepal. According to Balaraman (1996), tree leaves can be lopped in large quantities and converted into hay in the months of October-November when the rains recede and there is plenty of sunshine. However, this practice of conservation of tree leaves for feeding during the critical dry season has yet to come to the farmers' attention.

Anon (1990) reported that 9% of all dairy farmers in Nepal prepare hay and silage to meet animal feed requirements during the fodder deficit periods of the winter. A pilot test conducted under on-station conditions (at 1540 m, Pakhribas, Dhankuta) indicated that silage could be an alternative means of conserving seasonal forages (Subba, 2002). However, this might not be practical under farm conditions on a large scale due to the high spoilage percentage (Sharma and Pradhan, 1985 and Thapa, 1985) and the high labour investment required at peak labour times.

3.7.4 Conclusions

Farmers have used various terminologies and descriptive phrases to signify and differentiate some fodder quality attributes. In addition to the previously described fodder quality attributes *posilopan* and *obhanopan* the present study revealed a third key descriptor referring specifically to the duration of appetite satisfaction locally known as *adilopan*. In general more *obhano* fodders were also more *adilo* but there were also differences in terms of palatability and milk or butterfat productivity that resulted in some difference in the ranking of the same fodders for these two attributes. There were a few species that were noticeably more *obhano* than *adilo* and others that were much more highly ranked for *adilopan* than they were for *obhanopan*. The species that were more *obhano* than *adilo* were all quite highly *obhano* with dry leaves but were not standard cattle fodder. All the fodders that were more *adilo* than *obhano* were *chiso* fodders (low in their *obhano* score) and described as wet but were nevertheless associated with high intake that might be expected to satisfy appetite. Overall rankings of fodders for *posilopan* were clearly different from those for *obhanopan* or *adilopan*. As for *obhanopan* and *adilopan* there was generally more consistency in ranking amongst sites for more *posilo* fodders.

There were considerable changes in farmers' ranking for *obhanopan* with season. Rank scores for some tree species (*ghotli, bhimsenpati, kunyel* and *khasre khanyu*) were notably higher in winter than in summer whilst *obhanopan* of other tree species (*kimbu, khari, kabro, nebharo, patmiro* and *chamlayo*) was higher in summer than in the winter. A few species were however little affected by season. Similarly, farmers' ranking for *posilo* to *kamposilopan* changed with season. Some tree species (*patmiro, nebharo, kabro* and *kalobans)* were ranked as more *posilo* in summer than in winter whilst other tree species such as *amliso*, *dar* (*Boehmeria regulosa)* and *kunyel* (*Trema orientalis*) were ranked as more *posilo* in winter than in summer. In summer, the ranking for *obhanopan* and *posilopan* between men and women did not vary much but in winter there was some difference in the rankings for some species. Female farmers considered *khasre khanyu* and *amliso* as more *posilo* compared to the male farmers and ranked *chamlayo*, *kabro*, *malbans* and *rato siris* as more *obhano* than male farmers.

Obhano fodder also identified as *posilo* was reported to change either to *kamposilo* fodder due to senescence of leaves or to be *kamposilo* when the leaves were immature. However, *khasre khanyu* was reported to be highly palatable and *posilo* when young but to have a detrimental effect on animals when mature. Of the twelve different *obhano* tree species studied, the majority were ranked as more *posilo* in the summer than in the winter. Some tree species (*kalobans* and *bhimsenpati*) were less affected by season but *rato siris* was ranked more *posilo* in winter whilst *kunyel* was more *posilo* in summer than in the winter. Of the twelve *chiso* fodder tree species, there were only small differences in the farmers' rankings between seasons for the species *patmiro*, *chuletro* and *kabro*. *Koiralo* was ranked as more *posilo* during the winter than in summer, whilst *gogun* and *dar* were ranked more *posilo* during the summer than in winter.

In general, farmers' ranking between seasons did not differ strongly for species that were generally utilised throughout the year (*gogun*, *dudhilo* and *painyu*) and tree species that were regarded as most *obhano* such as *malbans* and *badahar*. There were some differences in ranking of *obhanopan* and *posilopan* between genders, perhaps associated with division of labour between the two.

The desirability of different fodder trees according to farmers was associated not only with the value of fodder for animals but also with management aspects of the tree and the effects of trees on crops. Tree species such as *dudhilo, rato siris, tanki, painyu, gogun* and *chuletro,* which are the most abundantly available in farmlands, are of low preference in terms of their fodder quality. Reasons for the selection of tree species was governed by a combination of animal factors, other properties of fodder trees such as their use for fuelwood and the quality of manure that results from feeding them, their ease of management and other socio-cultural reasons, including the use of leaves or shoots of some species as food or in ceremonial roles. There were no consistent differences in the knowledge held by farmers of different wealth, age or gender but there were some difference amongst sites.

Fuel and manure values were the most important factors in addition to fodder value that played a role in tree fodder selection. *Painyu* and *bhimsenpati*, considered as low fodder quality tree species, were reported to be *kharo* (desirable firewood). *Malbans* and *amliso,* highly preferred fodder species, were reported *kafalo* (undesirable firewood) and *rato siris* and *chuletro*, as *pocho* (undesirable firewood). Lowly ranked tree species in terms of feeding value such as *bhimsenpati* and *gogun* were also producing *tikau mal* (desirable manure) whilst highly rated fodder species such as *malbans* and *amliso* were considered *kamtikau mal* (undesirable manure).

The diminishing fodder resources of the dry season determine farmers' decisions for feeding and management of fodder. Farmers' knowledge system appeared to be crucial during this critical period in making decisions about the management and use of available fodder resources. Long leaf retention was a desirable characteristic but was dependent on the degree of exposure to sun, wind and on water relations as well as tree species. Based on the duration of leaf retention, farmers plan how to lop different trees.

In addition to differences according to species, usually trees receiving much solar radiation and strong wind were lopped before the trees under shade.

With the approach of the dry season, farmers reported that they practiced feeding mixtures of different fodder types with different quality attributes. They thought that feeding the animals a mixture of various fodders would improve intake, protect the animals from detrimental health effects and improve productivity. Furthermore, the fodder resources available could be efficiently utilized. A mixture of both *ramro* (palatable and nutritious) and *naramro* (less palatable and less nutritious) fodder types was reported to be the most common practice. However, while mixture of green fodder with cereal straw was common, most farmers did not generally practice mixing different green fodders with varied quality attributes. Farmers' selection of tree fodder was also be affected by their intended outputs, being different for milk, butterfat or liveweight gain. Almost all farmers reported that they ensured a supply of the best fodders (*posilo*) for productive animals (lactating cows and calves) and *adilo* fodders and other low quality but filling fodder for unproductive animals (oxen when idle and sterile cows).

The other main strategies reported by farmers to cope with dry season fodder shortages were adjustment of feeding systems, management of fodder resources and animals. Farmers store crop residues for feeding during the dry season. Rice straw was the most important crop residue but was not available in sufficient quantities for all farmers. Conservation of dry grasses was practiced at some sites but this was not common in others. Farmers decided planning and management of their fodder with respect to the farm animal herd size or altered herd size by culling unproductive animals or buying young animals. Cows were mated to coincide with the seasonal availability of forages. Migration of animals from one farm to another and the exchange of manure and feed with neighbours were other important strategies followed by farmers but such practices varied from place to place depending upon available fodder and size of animal holdings.

CHAPTER 4

IMPACT OF FEEDING DIFFERENT TREE FODDERS ON PRODUCTIVITY OF LACTATING COWS

Overview

Chapter 3 described the creation of a knowledge base on the use and management of tree fodders and examined local strategies to cope with dry season fodder shortages. In this chapter, the local *posilopan* descriptor of tree fodder value is examined for its correspondence with the productivity of lactating local cows in terms of milk and butterfat yield.

4.1 Introduction

Livestock play an important role in sustaining rural livelihoods in the mid-hills of Nepal. They contribute about 17% to the national GDP and 32% to the agricultural GDP (Anon, 2000a). Cows comprise 67% of the total large ruminant population. However, in 1999, only about 12% of the total cow population was lactating (Anon, 2000b) and the productivity of local cows in terms of milk production was very low compared to exotic breeds.

Tree fodders are an important source of nutrition to supplement low quality dry roughages during the dry season (mid November to mid June) when feeds are scarce (Section 2.4.1 and 3.9). Farmers assess the quality of different tree fodders, based on animal performance, and visible effects of feeding them in terms of milk yield, butterfat content and animal health (Section 3.4.1.1). Although tree fodders have been used traditionally in Nepal for many years, investigation of the biological basis underlying their local usage is a recent but important line of research.

Farmers in the hills of Nepal possess a sophisticated body of knowledge about the nutritive value of tree fodder (Thapa *et al.,* 1997) that is associated with their animal management practices (Section 3.9.1). Previous investigations of farmers' knowledge have revealed two local descriptors of tree fodder value, *posilopan*, meaning nutritiousness, and *obhanopan* literally meaning dryness and warmness but relating to palatability, digestibility and dung consistency (Thapa *et al.*, 1997). These were widely and consistently used by farmers (Walker *et al.*, 1999). In the present research, a third local descriptor, *adilopan*, referring specifically to the duration of appetite satisfaction, was found to be widely used by eastern hill farmers (Section 3.4.1.3).

Walker *et al.* (1999) found that farmers' ranking of fodders for *obhanopan* and *posilopan* were independent of each other, suggesting that farmers' knowledge was sophisticated in differentiating nutritive value into more than one component. Comparison of *in vitro* chemical analysis of different fodders, also ranked in terms of their *posilopan* by farmers, suggested a link between protein supply and *posilopan* rank (Thorne *et al.,* 1999). In the present research, this line of enquiry is taken further by exploring the biological interpretation of the local *posilopan* descriptor using, *in vivo*, feeding trials.

Limited work has been done to assess the feeding value of tree fodder in Nepal under on-farm conditions. Those studies which have been done have conflicting results and are inadequate to improve livestock feeding practices (Paudel and Rasali, 1996) in Nepal. On-farm studies in many ways are more difficult to conduct than on-station studies, yet they are worth attempting because they give much more realistic information about the performance of animals under the prevailing local management practice (Gatenby, 1989).

The objective of the research reported in this chapter was to explore the relationship between farmers' assessment of the *posilopan* of tree fodders and their impact on animal performance, in terms of milk and butterfat yield measured in on farm feeding trials.

4.2 Materials and methods

This study was carried out by determining the response of feeding 14 of the most commonly available tree fodders as a supplement to the basal diet of 78 lactating local cows under on-farm conditions in the eastern hills of Nepal. The response variables measured were milk and butterfat yield.

4.2.1 Experimental sites

Prior to the experimentation, inventories of the households maintaining lactating local cows were taken in the villages located within three hours walking distance from the Agricultural Research Station, Pakhribas (ARS-P). Past experience had shown that the milk collected from farms more than three hours walking distance away was curdled and unsuitable for laboratory analysis by the time it reached the research station. Inventories were made by visiting households who were identified through local informants met on transect walks. The age, calving date and parity of each lactating cow were recorded. A list of the tree fodder species available for feeding in each farm household was made so as to identify suitable fodder tree species for the feeding experiment.

The experiment was conducted at Belahara (Patle), Pakhribas (Salbote and Pakhribas), Phalante, and Hattikharka village development committees (VDCs) during the dry season from October to March 1999.

4.2.2 Selection of tree species

Fourteen tree fodder species (Table 4.1) were selected for study. These species were identified as the most commonly used dry season fodder trees in Dhankuta district in the eastern hills of Nepal. Although *painyu* (*Prunus cerasoides*) was also a common fodder tree within the list of the fifteen most common species identified for the region, none of the farmers was interested in participating in a *painyu* feeding trial. This was because of their strong perception that *painyu* could cause adverse effects on health and productivity of large ruminants (Section 3.7.2). Even though it is not a good fodder for large ruminants, it is considered good for sheep and goats (Thapa, 1994). Another reason that *painyu* is a common tree on private land may be because of its other uses e.g. high fuel (Section 3.8.1) and timber values (Section 3.7.2).

Table 4.1 List of common and scientific names of tree species available and used for the feeding trial.

Tree species	Scientific name
Amliso	*Thysanolaena maxima*
Badahar	*Artocarpus lakoocha*
Dudhilo	*Ficus nerrifolia* var *nemoralis*
Ghotli	*Sambucus hookeri*
Gogun	*Saurauria nepaulensis*
Kalobans	*Bamboosa hookeri*
Khari	*Celtis australis*
Khasre khanyu	*Ficus semicordata var semicordata*
Kimbu	*Morus alba*
Malbans	*Bamboosa nutans*
Nebharo	*Ficus auriculata*
Patmiro	*Litsea polyantha*
Rai khanyu	*Ficus semicordata var montana*
Tanki	*Bauhinia purpurea*

4.2.3 Ranking of tree species

Details about farmers' preferences for tree fodders are described in Section 3.5. Ranking of tree fodders here was carried out specifically amongst the tree species available to the households and used in the on-farm feeding trials.

A randomly selected group of 20 small farmers representing a range of ethnic groups, and involved in the milk trade, were interviewed separately in two groups according to gender (10 men and 10 women). These farmers were representative of those who normally come every morning to sell milk at milk collection depots at Hile, in Dhankuta district. The farmers who attended these group interviews were from Hile, Barbote, Pakhribas and Chungbang villages. Of the farmers interviewed, only five were subsequently involved in the feeding trial.

The farmers were asked to evaluate the species listed in Table 1 in terms of *posilopan*, their effects individually on milk and butterfat yields and to rank the species in terms of their overall preference amongst the species. Ranking was done by the group of farmers with the help of cards with the names of tree fodders written on them. Farmers arranged the cards from highest to lowest for each attribute being ranked. The order was crosschecked by asking the group to rearrange from lowest to the highest for each attribute. Finally, each group discussed the ranking and arrived at a group consensus.

4.2.4 Selection of animals

From the data gathered on lactating cows (described above), a total of 78 lactating cows, with owner farmers interested in participating in the feeding trial and possessing sufficient tree fodder species, were purposively selected for the study. The selected cows were between 8 and 17 weeks into their lactation at the start of the study. The cows were aged between 3 to 10 years and at a parity of between 1 and 8. The selected animals were isolated during the trial period from other animals in the shed in which they were kept. Before the experiment, all animals were drenched with a broad spectrum anthemintic, Albendazole.

Table 4.2. Number of cows fed each tree species and their average lactation number, age and parity

Tree species	No of cows	Lactation period (week)	Age (yr)	Parity (no)
Amliso	3	8	7.3	2.3
Badahar	4	8	6	3
Dudhilo	9	13	8	4
Ghotli	11	9	8	3
Gogun	4	12	7	4
Kalobans	3	13	7	3
Khari	8	15	8	4
Khasre khanyu	8	14	7	3
Kimbu	2	17	8	3
Malbans	6	10	6	3
Nebharo	4	17	7.5	3.3
Patmiro	3	10	4	2
Rai khanyu	9	15	8	3
Tanki	4	9	9	5

Of the total selected lactating cows, the number of cows selected in Hattikharka, Hile, Pakhribas, Patle, Phalante and Salbote were 7, 19, 10, 8, 22 and 12 respectively. The mean live weight of the cows was 185 kg (±5.07 SEM) and all of the cows were local breeds. The number of cows fed each tree species and their average lactation numbers, age and parity are shown in Table 4.2.

Before launching the experiment, the purpose of the study was explained to farmers in the study areas. The participating farmers were offered details of how they might eventually benefit from its findings.

4.2.5 Dietary treatment regimes

Each treatment diet (tree fodder supplement) was supplied on a 4% live weight basis with a basal diet according to local practice. The basal diet was mainly composed of rice straw at approximately 1% live weight and homemade concentrates (including some seasonal greens and waste vegetables as per farmers' practice). Participating farmers were requested to maintain the basal diets as constant as possible throughout the experimental period. The total diet was divided into two equal meals, which one feed in the morning, and another in the afternoon and water provided ad libitum as per local practice.

4.2.5.1 Data collected

4.2.5.1.1 Feed consumption

Monitoring of feed intake/refusal was carried out at three-day intervals by mobile support staff. The farmers assisted the support staff to record feed intake and refusals. Food offered or refused was weighed using a spring balance (capacity 4kg±0.1), recorded on a data sheet (Appendix 4.1) and fodder samples were collected and sent to the laboratory for analysis.

4.2.5.1.2 Milk yields

Prior to the experiment, participating farmers were provided with data sheets (Appendix 4.2) to record daily milk yield and with 500 ml and 1000 ml graduated plastic jugs.

The experimental cows were milked twice a day, between 6:30 and 7:30 hrs in the morning, and in the evening at approximately 18 hrs according to normal practice. The participating farmers were supplied with record sheets and a file for each cow to assist the recording of milk yield at each time of milking. Field-based support staff also regularly monitored the milk yield recording for the whole experimental period to check that the instructions were being carried out correctly. The milk samples were collected on the first day of feeding (day 'zero') and at three-day intervals thereafter until day 21.

4.2.5.1.3 Farmers' views on animal performance

In order to inform the participating farmers of the progress of the feeding experiment, two meetings were organised. One was held halfway through the experiment and the other after the completion of the experiment. The meetings were held in two groups for all farmers participating in the feeding trial to discuss the laboratory results of the milk analysis in response to feeding of tree fodders. This meeting also assessed the extent of their knowledge of tree fodder quality and how it conformed to the observations made in the study. The meeting was held at the Agricultural Research Station, Pakhribas, Dhankuta.

4.2.6 Collection and analysis of feeds and milk

4.2.6.1 Collection and analysis of feeds

In order to assess nutrient intake of the experimental animals, samples of basal feeds and the tree fodders were sampled and dispatched to the laboratory for nutritional analysis. In the lab, the feed samples were chopped, weighed and dried at 60 ±5 °C in a forced hot air oven to a constant weight, and the dry matter was determined. Crude protein (N x 6.25) was determined according to conventional techniques (AOAC, 1981).

4.2.6.2 Collection and analysis of milk

Fresh milk was collected in the morning for laboratory analysis by dipping a ladle into well-mixed milk in a container. From each cow, a milk sample of approximately 500 ml was collected in clean plastic containers, with screw caps, labelled with farmer's name, collection date, name of tree fodder species fed and name of cow) and transported, undisturbed, to the laboratory as soon as possible. Each farmer was paid for the cost of the milk collected for laboratory analysis at a price a little higher than the local price. This was to ensure that the milk could be received unadulterated as a whole milk for laboratory analysis because local milk vendors often add water to milk to boost their profits. In the laboratory, milk samples were analysed for butterfat following Gerber's fat analysis technique.

4.2.7 Statistical analysis

Regression analysis was carried out to examine yields of milk and butterfat content over time. Response of feeding tree fodders to changes in the levels of milk and butterfat were analysed by repeated measures using orthogonal polynomial coefficients (Mead *et al.*, 2003). Changes in milk yield and butterfat contents during the experimental periods were plotted over time for each tree species to examine the trend for linearity of the data. Slopes for each treatment were derived from multiplication of the milk (butterfat) data for each experimental period with the orthogonal polynomial coefficients derived from the table (Fisher and Yates, 1963). The slope estimates derived for each treatment were used as variables and subjected to analysis of variance using the General Linear Model (GLM) procedure in the Minitab statistical program (Minitab for Windows 2000, release 13.31).

4.3 RESULTS

4.3.1 Ranking of tree fodders by local farmers

The mean rank order of the tree fodders for the two consensual groups of 10 male and 10 female farmers for milk and butterfat yield is presented in Table 4.3.

Table 4.3 Overall rank orders of tree fodders for milk and butterfat yield. Mean order from two consensual groups of 10 male and 10 female farmers (figure in brackets are the rank order, 14 is the highly ranked). Rank scoring for *posilopan* is derived from Chapter 3, the figure in brackets is the standard deviation) (higher the score higher is the ranking)

Milk promoting tree species	Butterfat promoting tree species	*Total rank score (milk & butter fat)*	*Posilopan*
Badahar (14)	*Badahar (13)*	*27*	*87.2 (3.01)*
Malbans (12)	*Malbans (14)*	*26*	*87.8(5.96)*
Ghotli (13)	*Ghotli (11)*	*24*	*na*
Amliso (7)	*Amliso (12)*	*19*	*84.4 (6.16)*
Rai khanyu (6)	*Rai khanyu (10)*	*16*	*64.4 (3.96)*
Tanki (9)	*Tanki (7)*	*16*	*60.6 (5.59)*
Nebharo (11)	*Nebharo (4)*	*15*	*72.2 (4.84)*
Khari (10)	*Khari (5)*	*15*	*na*
Kimbu (8)	*Kimbu (6)*	*14*	*na*
Khasre khanyu (5)	*Khasre khanyu (9)*	*14*	*31.1 (3.42)*
Patmiro (2)	*Patmiro (8)*	*10*	*48.9 (6.16)*
Dudhilo (4)	*Dudhilo (2)*	*6*	*38.3 (4.03)*
Gogun (3)	*Gogun (3)*	*6*	*28.9 (3.21)*
Kalobans (1)	*Kalobans (1)*	*2*	

There was generally a good agreement between ranking of tree species on *posilopan* and the combined rankings of milk and butterfat yield.

Several tree species that farmers ranked highly for milk yield they also ranked as high in terms of butterfat yield, for example *badahar*, *ghotli* and *malbans*. Similarly, some tree species ranked as low for milk yield were low for butterfat promoting, for example *gogun*, *dudhilo* and *kalobans* (Table 4.3). This relationship did not however, hold for all tree species since although *nebharo* and *khari* were ranked as high milk promoting tree species they were ranked as low for butterfat whilst the reverse was true for *amliso*, *rai khanyu*, *khasre khanyu* and *patmiro*.

4.3.2 Intake of feeds

Dry matter intake of tree fodder (kg head^{-1} day^{-1}), total dry matter intake (kg head^{-1} day^{-1}), crude protein intake from tree fodders (kg head^{-1} day^{-1}) and total crude protein intake (kg head^{-1} day^{-1}) significantly differed ($p<0.001$) amongst the treatment diets (Table 4.4). Average dry matter intake of tree fodder and total crude protein intakes were highest for diets containing *malbans* (Table 4.4), which is regarded as the most *posilo* fodder species. Diets containing *kalobans*, considered the least *posilo* fodder, contained the lowest total crude protein. In the animals on *gogun*, although tree fodder intake was high, it was one of the least preferred fodder tree species among farmers as a *posilo* fodder.

Table 4.4 Mean dry matter and crude protein intake (sem) for each treatment

Fodder tree species (n = no of cows)	Tree fodder DMI (kg head^{-1} day^{-1}) (sem)	Rice straw DMI (kg head^{-1} day^{-1}) (sem)	*khole* DMI (kg head^{-1}day^{-1}) (sem)	Total DMI (kg head^{-1}day^{-1}) (sem)	Tree fodder CP intake (g head^{-1} day^{-1}) (sem)	Total CP intake (g head^{-1} day^{-1}) (sem)
Malbans (n=6)	3.03 (0.376)	3.97 (0.392)	1.47 (0.200)	8.47 (0.514)	537 (66.54)	862 (67.36)
Badahar (n=4)	2.24 (0.075)	1.84 (0.270)	0.66 (0.265)	4.74 (0.510)	378 (12.5)	526 (49)
Amliso (n=3)	1.52 (0.104)	4.51 (0.595)	1.55 (0.202)	7.58 (0.895)	207 (13.86)	559 (59.47)
Nebharo (n=4)	2.30 (0.220)	4.01 (0.300)	1.33 (0.180)	7.64 (0.370)	353 (34)	660 (28)
Kimbu (n=2)	0.69 (0.332)	4.71 (1.351)	2.22 (0.445)	7.62 (2.135)	124 (60.10)	577 (163.3)
Tanki (n=4)	2.84 (0.130)	2.92 (0.110)	0.89 (0.145)	6.65 (0.150)	526 (24)	738 (33.5)
Ghotli (n=11)	1.93 (0.169)	5.42 (0.407)	1.66 (0.112)	9.00 (0.389)	320 (28.04)	715 (27.4)
Khari (n=8)	1.25 (0.099)	6.21 (0.247)	1.95 (0.265)	9.41 (0.343)	208 (16.62)	667 (35.35)
Rai khanyu (n=9)	1.89 (0.137)	4.27 (0.183)	1.76 (0.173)	7.92 (0.287)	244 (17.67)	618 (29.67)
Khasre khanyu (n=8)	1.88 (0.230)	4.52 (0.870)	1.09 (0.205)	7.49 (0.834)	241 (29.34)	530 (36.06)
Dudhilo (n=9)	1.07 (0.053)	4.16 (0.600)	1.66 (0.083)	6.88 (0.633)	179 (9.0)	536 (25.3)
Patmiro (n=3)	1.64 (0.335)	7.68 (0.774)	1.03 (0.144)	10.35 (1.097)	241 (49.6)	616 (79.01)
Gogun (n=4)	2.38 (0.33)	3.54 (0.280)	1.30 (0.220)	7.22 (0.755)	348 (48)	636 (83)
Kalobans (n=3)	1.63 (0.075)	3.15 (0.052)	0.86 (0.064)	5.64 (0.052)	254 (11.55)	469 (12.12)
P value	0.000	0.000	0.000	0.000	0.000	0.000

The intake of *kimbu* was significantly lower (0.69 kg head^{-1} day^{-1}) than other tree species and there was a correspondingly low intake of crude protein from tree fodder in this species. However, the highest (2.22 kg head^{-1} day^{-1}) of *khole* resulted in a total crude protein intake similar to that in other experimental tree species. Animals in the *badahar* group had the lowest dry matter intake whilst highest total dry matter intake (10 kg head^{-1} day^{-1}) was observed in the animals maintained on *patmiro*. This was due to high intake of rice straw (as a basal food). Similarly, the high intake of dry matter (9 kg head^{-1} day^{-1}) in the *ghotli* and *khari* groups was derived from high intake of rice straw. Intake of *khole* was generally lower in the animals maintained on the *badahar*, *tanki* and *kalobans* diets (< 1 kg dm head^{-1} day^{-1}) compared to the intake of other groups of animals (intake from 1 to 2 kg dm head^{-1} day^{-1}).

4.3.3 Milk and butterfat yield

Milk and butterfat yields at three day intervals during the experiment are given in Figure 4.1a and 4.1b respectively. There were differences in milk yield of cows at the initial stage that ranged from 0.98 l day^{-1} in the *badahar* group to 3.70 l day^{-1} in the *amliso* group. The butterfat % recorded at the initial stage ranged from 3.77% in the *malbans* group to 5.25% in the *kimbu* group.

When the milk yield for each observation period was compared between treatments, there was a clear likelihood that there were significant differences amongst treatment groups decreased over time (Table 4.5). Difference in the milk yield amongst treatments was significant only until day 6 of observation and was not significant beyond this time.

Table 4.5. Probability values of differences amongst treatment groups of animals receiving different tree fodder diets, for milk and butter fat yield, at each observation.

Observation (day)	P value for milk yield	P value for butterfat yield
0	0.011	0.005
3	0.028	0.005
6	0.037	0.011
9	0.054	0.002
12	0.067	0.004
15	0.069	0.002
18	0.082	0.001
21	0.082	0.001

Conversely, in the case of butterfat yield, a general tendency of increasing likelihood of significant differences amongst the treatment groups over time was observed. There were significant differences amongst treatment groups on all sampling occasions (Table 4.5).

Average trends in milk and butterfat yields over time derived from the analysis of orthogonal polynomial coefficients are presented in Table 4.6. Analysis of variance showed that there was a significant difference amongst treatment diets for milk ($p<0.01$) and butterfat yield $p<0.001$) over the experimental period.

Figure 4.1a Milk yield: Response of feeding tree fodders on milk yield in lactating cows. X-axis is sampling time from onset of treatment diet (days) treatment diet was ceased at day 21 and Y-axis is milk yield (litre cow^{-1} day^{-1}). Figure 4.1b Butterfat yield: Response of feeding tree fodders on butterfat yield in lactating cows. X-axis is sampling interval (day) and Y-axis is butterfat yield (%)

Badahar (4)

Ghotli (11)

Malbans (6)

Nebharo (4)

Khari (8)

Tanki (4)

Figure 4.1a Milk yield

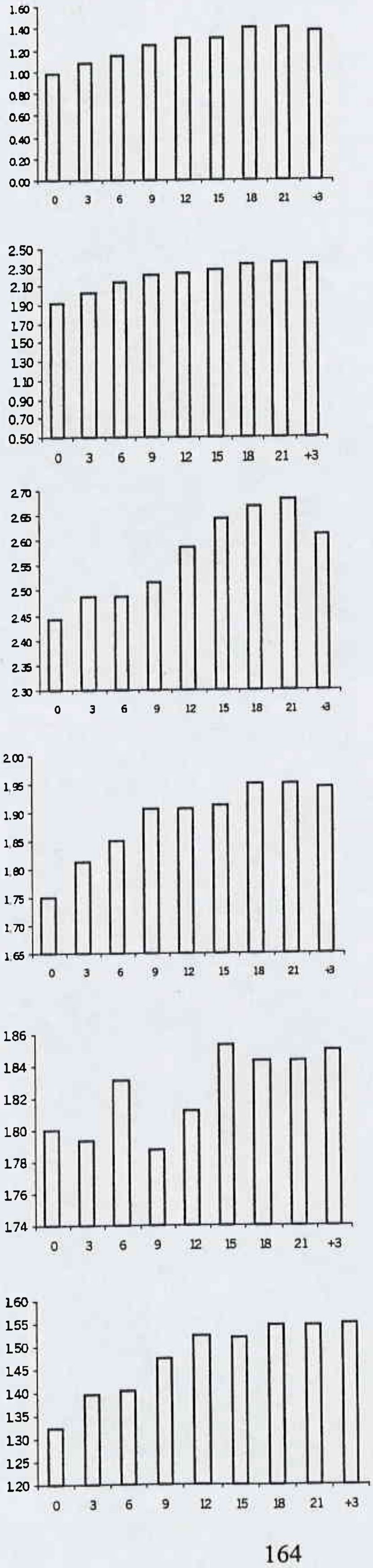
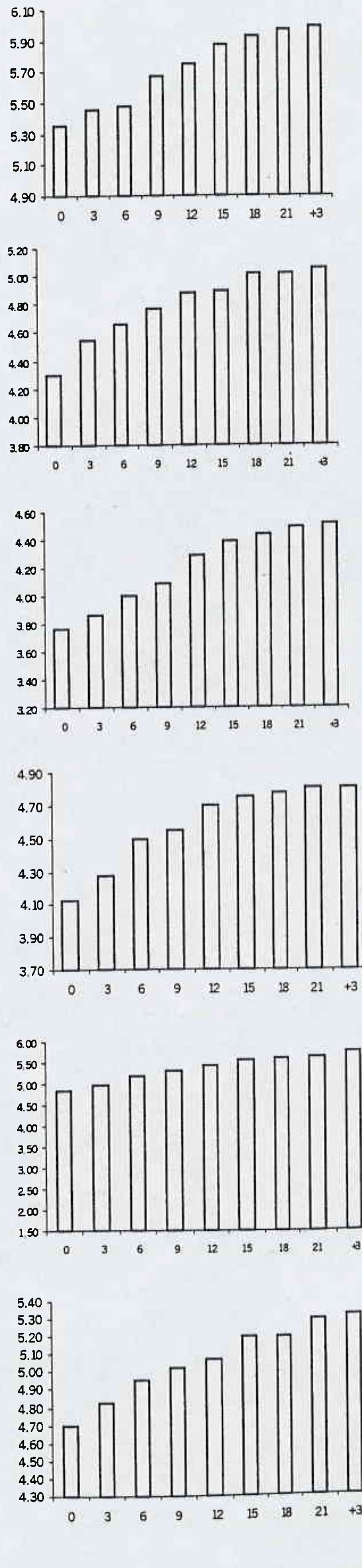
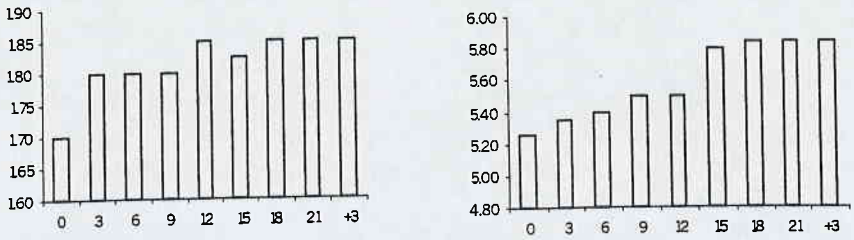


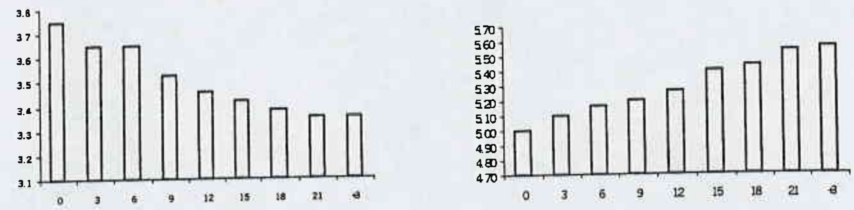
Figure 4.1b Butterfat yield



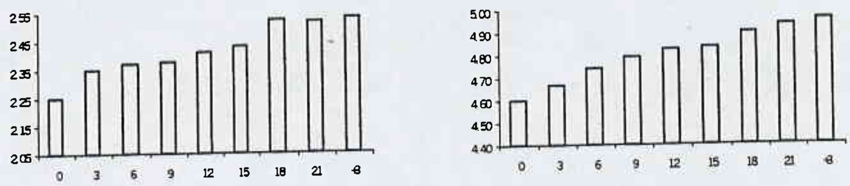
Kimboo (n=2)



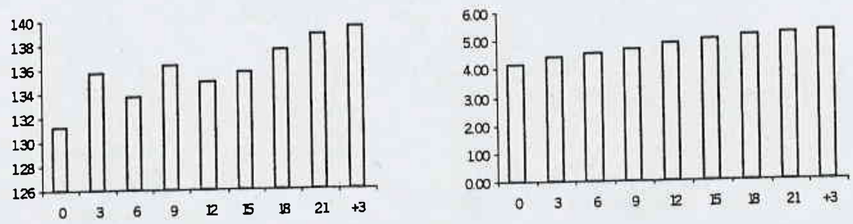
Amliso (n=3)



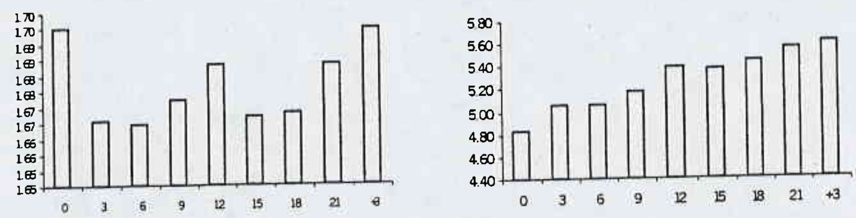
Rai khanvu (n=9)



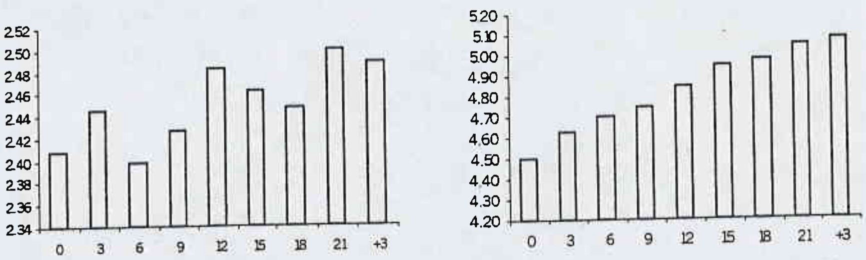
Khasre khanvu (n=8)



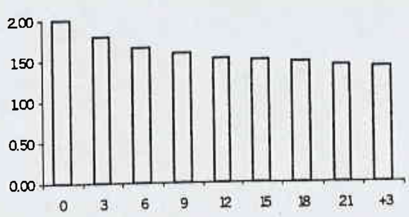
Dudhilo (n=9)



Gogun (n=4)



Patmiro (n=3)



Kalobans (n=3)

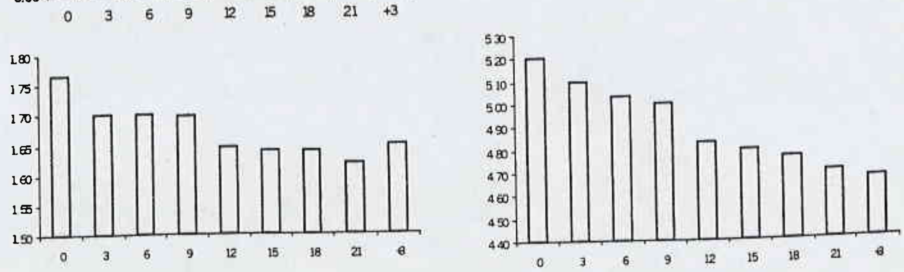


Table 4.6. Average slopes for changes in milk and butterfat yields over time for cows supplemented with different fodder tree species.

Farmers' rank order for milk yield (high to low)	Milk yield Mean slope (sd)	Farmers' rank order for butterfat yield (high to low)	Butterfat Mean slope (sd)
Badahar	3.07 (1.245)	*Malbans*	6.02 (4.822)
Ghotli	3.02 (3.793)	*Badahar*	5.27 (3.606)
Malbans	1.77 (1.282)	*Amliso*	4.30 (1.386)
Nebharo	1.40 (0.735)	*Ghotli*	5.24 (2.357)
Khari	0.44 (1.815)	*Rai khanyu*	2.58 (1.869)
Tanki	1.72 (0.699)	*Khasre khanyu*	8.50 (2.955)
Kimbu	0.90 (0.707)	*Patmiro**	NA
Amliso	-3.13 (0.808)	*Tanki*	4.60 (1.219)
Rai khanyu	2.00 (3.147)	*Kimbu*	5.10 (1.131)
Khasre khanyu	0.49 (2.233)	*Khari*	6.84 (2.018)
Dudhilo	0.06 (2.205)	*Nebharo*	5.02 (1.520)
Gogun	0.62 (3.730)	*Gogun*	4.32 (2.895)
Patmiro	-4.00 (1.389)	*Dudhilo*	5.52 (5.408)
Kalobans	-0.87 (0.462)	*Kalobans*	-4.07 (1.447)
p-value	0.002		0.000

*milk was unfit for laboratory butterfat analysis when it arrived from the field.

Results in Table 4.6 show how milk yield changed over time as a result of supplying different tree fodders. A high positive rate of change was observed for *badahar* and *ghotli* (slope about 3); intermediate for *rai khanyu*, *malbans*, *tanki* and *nebharo* (slope between 1.0 to 2.0) and low for *kimbu*, *gogun*, *khasre khanyu*, *khari* and *dudhilo* (slope less than 1.0). In the case of *amliso*, *kalobans* and *patmiro*, there was drop in yield which was highest for *patmiro* followed by *amliso* and *kalobans*. There was an increase in butterfat yield over the observation period for all tree species except *kalobans*, for which there was a decrease. The rate of change of butterfat yield was high for *khasre khanyu* (slope >8.0) and for *malbans* and *khari* (slope between 6 and 7). The rate of change in butterfat yield was similar for all other tree fodder species (slopes around 5) except for *rai khanyu* that showed a low rate of change (slope about 2.5).

When the gain in milk yield was calculated the difference between the 'average production' while the experimental diet was fed and initial production level (at day 0) expressed as a percentage, the highest gain in milk yield (>14%) was observed for *badahar*, *ghotli* and *tanki* (Table 4.7). Several tree species were associated with reductions in milk yield: *patmiro, kalobans, amliso* and *dudhilo*. The reduction in milk yield in the case of *patmiro* was over 20%.

Table 4.7 Percentage changes in milk and butterfat levels in response to feeding of tree fodders.

Farmers' rank order for milk yield (high to low)	Change* in milk yield (%)	Farmers' rank order for butterfat yield (high to low)	Change* in butterfat yield (%)
Badahar	*Badahar (26.8)*	*Malbans*	*Khasre khanyu (15.1)*
Ghotli	*Ghotli (17.4)*	*Badahar*	*Nebharo (12.7)*
Malbans	*Tanki (14.4)*	*Amliso*	*Ghotli (12.1)*
Nebharo	*Rai khanyu (10.2)*	*Ghotli*	*Khari (11.9)*
Khari	*Malbans (7.6)*	*Rai khanyu*	*Malbans (11.0)*
Tanki	*Kimbu (7.4)*	*Khasre khanyu*	*Dudhilo (10.3)*
Kimbu	*Nebharo (5.5)*	*Patmiro*	*NA*
Amliso	*Khasre khanyu (4.7)*	*Tanki*	*Tanki (8.1)*
Rai khanyu	*Gogun (2.2)*	*Kimbu*	*Gogun (7.6)*
Khasre khanyu	*khari (1.3)*	*Khari*	*Amliso (6.0)*
Dudhilo	*Dudhilo (-1.7)*	*Nebharo*	*Kimbu (5.8)*
Gogun	*Amliso (-7.0)*	*Gogun*	*Badahar (5.7)*
Patmiro	*Kalobans (-7.6)*	*Dudhilo*	*Rai khanyu (4.6)*
Kalobans	*Patmiro (-21.4)*	*Kalobans*	*Kalobans (-6.0)*

Calculated as the percentage of the difference between the 'average production' (i.e. average value of the measurements at days 3, 6, 9, 12, 15, 18 and 21 post experimental feeding) and the production at day 0.

For butterfat yield, the highest gain was observed for *khasre khanyu* followed by *nebharo, ghotli, khari, malbans* and *dudhilo*, all with gains higher than 10%. Apart from *kalobans*, all other tree species caused some increase in butterfat yield with gains from about 4 to 8%. *Kalobans* was the only species observed that caused reduction in butterfat yield.

4.3.4 Farmers' perceptions of the trial results

Interpretations regarding the impact of feeding tree fodders by individual participant farmers are shown in Table 4.8.

Table 4.8. Summary of farmer responses on the impact of tree fodder supplementation on milk and butterfat yield.

Tree species	Milk production				Butterfat production				Summary of farmers responses
	+	-	No effect	Don't know	+	–	No effect	Don't know	
Malbans	4	0	1	1	5	0	1	0	Increased milk and butterfat yield. Improved animal health. Passed firm dung.
Badahar	4	0	0	0	3	0	1	0	Increased milk and butterfat yield. Increased appetite, more palatable, improved health of animals.
Amliso	1	2	0	0	3	0	0	0	Improved in butterfat yield but dropped in milk yield. Improved health of animals. Satisfied appetite. Passed firm dung.
Rai khanyu	5	1	3	0	4	0	2	3	Increased in milk and butterfat yield. Improved health slightly.
Tanki	3	0	1	0	2	0	0	2	Increased milk and butterfat yield. Food intake dropped slightly. No effect on animal health.
Nebharo	4	0	0	0	2	1	0	1	Increased milk yield, but slight increase in butterfat yield. Improved in the health of animals.
Kalobans	0	2	1	0	0	2	1	0	Drop in milk and butterfat yield. Slight decline in the health of animals.
Kimbu	2	0	0	0	2	0	0	0	Increased milk and butterfat yield. Slight improvement on animal health.
Khari	5	1	2	0	4	0	2	2	Improved milk and butterfat yield. Slight improvement on animal health.
Ghotli	6	0	2	1	5	0	2	2	Improved milk and butterfat yield. Slight improvement on animal health. Passed firm dung.
Khasre khanyu	4	1	3	0	2	3	2	1	Increase in milk yield but dropped in butterfat yield. Dropped feed intake, slightly lost body weight. Caused constipation.
Gogun	2	0	1	1	2	0	1	1	Slight increase in milk and butterfat yield but no effect on animal health.
Dudhilo	0	6	1	2	3	1	1	4	Milk yield dropped but butterfat level increased slightly. Regular feeding caused diarrhoea and weakness.

Note: Numbers are the number of respondents agreeing to '+' = increase in milk/butterfat production, '–' = decrease in milk/butterfat production, no effect or don't know.

The majority of participating farmers noticed improvement in milk and butterfat yield in response to the supply of most of the experimental tree fodders (Table 4.8). The majority of participant farmers in the *dudhilo*, *kalobans* and *amliso* groups, however, reported that there was a drop in milk yield in their cows as a result of feeding these fodder species. A general increase in milk yield was perceived by farmers feeding *badahar*, *kimbu*, *tanki*, *ghotli*, *nebharo* and *malbans* whereas this was less clear for farmers in the *rai khanyu*, *khasre khanyu* and *khari* groups, with a considerable number of farmers noting a reduction or no effect on milk productivity.

In the case of butterfat yield, farmers in the *malbans*, *badahar*, *kimbu* and *amliso* groups reported that there was an increase in butterfat yield as a result of feeding these fodder species. Farmers who fed *kalobans* to their animals reported that there was a drop in butterfat yield. Opinions of farmers varied about the impact of feeding the remaining tree species i.e. *rai khanyu*, *tanki*, *nebharo*, *khari*, *ghotli*, *khasre khanyu*, *gogun* and *dudhilo*. A considerable number of farmers found it difficult to interpret and explain whether or not there was an impact of these tree species on butterfat production (Table 4.8). This was particularly true for *dudhilo*, *rai khanyu*, *tanki* and *khari*.

As reported by farmers, except for *dudhilo, khasre khanyu* and *kalobans*, in general tree fodders improved the health of their animals. It was also reported that *dudhilo, khasre khanyu* and *kalobans* slightly decreased the health of animals through a decrease in feed intake (*khasre khanyu* and *kalobans*) and digestive disturbances (*dudhilo*).

4.4 Discussion

Feed is offered to animals by farmers according to availability, palatability, cost and experience of what seems to work in practice. The farmers assess responses to feeds in terms of milk yield in their lactating cows. The traditional approach of farmers to feeding animals during the dry winter season is based on the hypothesis that feeds are provided for maintenance and production of a little milk. The farmers keep a close eye on performance of their animals and adjust the supply of different fodder resources and homemade concentrate. Achieving the desired outputs is an art and skill that individuals have learned through practice and experience. As a consequence, knowledge may vary amongst individuals and according to gender (Section 3.6). Consistency of ranking by gender for both milk and butterfat yield at the extremes of the scale but inconsistency in the intermediate range suggests that the ordering of intermediate species may reflect other gender specific tree attributes such as their phenology.

Badahar and *ghotli* were ranked highest as milk promoting tree species. The milk yield obtained from feeding these tree species confirmed that they do stimulate an increase in milk production in lactating cows. One participant, who also participated in the feeding trials of *khasre khanyu* and *tanki*, reported that *badahar* is a better fodder compared to either *tanki* or *khasre khanyu*. He reported that a loss of body condition of animals due to feeding *khasre khanyu* gradually recovered when *badahar* was subsequently included in their diet.

In general the measured butterfat content associated with different fodders was only weakly correlated with the farmer ranking. When this was discussed with the farmers groups, it became evident that direct observation of impacts of particular fodders on butterfat yield were complicated by the nature of their marketing practices. Three farmers reported that they blended cow's milk with buffalos' milk for *ghee* or yoghurt production. This kind of practice was generally used where the households maintained a mixture of ruminant species, particularly local and low producing animals. Other farmers who were from areas near road heads, mainly from Patle, near Dhankuta district headquarters, where most farmers sell milk to the collection points nearby, reported that they maintain up to date records of butterfat since the price of the milk is fixed on the basis of the resultant percentage of butterfat. However, farmers holding more than one cow mix the milk before they take it to the market. The butterfat content thus represents the mixture of different animals in a household and maybe derived from the feeding of a mixture of different fodder resources. Moreover, most farmers near road heads with accessibility to markets tend to utilize more concentrate to improve animal productivity (Section 2.4.2.4), which may mask the effect of a tree fodder species in question.

Thapa (1994) reported that local farmers in Solma (in Terhathum district) evaluate *ghee* promoting fodder tree species on the basis of the thickness or thinness of milk (corresponding with high or low butterfat contents respectively). Farmers judge butterfat content by observing the cream that remains after the milk is boiled, which is done normally soon after the milk is collected. This knowledge is commonly used in other areas in the eastern middle hills to discriminate fodder quality in terms of *ghee* productivity. But accuracy of the yield can only be predicted if the milk was coming from the same cow fed on the same tree fodder.

It is also possible that the farmers' assessment of butterfat promoting tree species may have been based on total yield combining fat content and milk yield. When the % difference in butterfat yield (% change in butterfat yield between day '0' and the average of the other days) was compared with the farmers' ranking, a slightly better relationship was observed (Table 4.9) with *badahar* and *ghotli* falling in the higher part of the range and *gogun*, *dudhilo* and *kalobans* in the lower part.

Table 4.9 Percentage difference (wt/wt) of butterfat yield between day 21 and day 0

Farmers' rank order for butterfat yield (high to low)	Order (high to low) based on measured % difference
Malbans	*Badahar (34.0)*
Badahar	*Ghotli (31.6)*
Amliso	*Tanki (23.7)*
Ghotli	*Khasre khanyu (20.5)*
Rai khanyu	*Malbans (19.4)*
Khasre khanyu	*Nebharo (18.9)*
Tanki	*Rai khanyu (15.3)*
Kimbu	*Kimbu (13.6)*
Khari	*Khari (13.3)*
Nebharo	*Gogun (9.9)*
Gogun	*Dudhilo (8.4)*
Dudhilo	*Amliso (-1.4)*
Kalobans	*Kalobans (-13.1)*

The higher correspondence in ranking of tree fodders for milk yield than butterfat in relation to the animal response data could be because the farmers have day-to-day records of milk yield of individual animals and so can see the response of various fodder types. It is common among family members to discuss the performance of their lactating cows in terms of milk yields. Based on the current milk yield of the cows, the household head often makes plans to improve feeding if he or she thinks this is necessary. It is also a general practice of local farmers to keep records of the productivity of their cows particularly in terms of milk yields and the value of a cow, in terms of the sale price it could attain, is dependent on the amount of milk it produces.

Assessment of tree fodders under on-farm conditions is a new area of research particularly in terms of visible outputs of animal performance. Limited literature on *badahar* supplementation suggests that it significantly improves the productivity of animals in terms of milk yield or butterfat yield compared to either the basal diet or farmer's usual feeding practice (Poudel and Rasali, 1996). However, the offer rate of *badahar* was high at 40 kg day^{-1} (fresh wt). Similarly, Rana *et al.*, (2000) obtained significant increase in milk and butterfat yield with *badahar* supplementation compared to either treated or untreated rice straw in lactating buffalo.

Shrestha and Pakhrin (1989) observed an increase in milk yield in lactating buffalo in response to feeding of *tanki*, *khasre khanyu*, *ghotli* and *rai khanyu* under on-farm conditions. However, the order of milk yield did not correspond with the local farmers' preference order particularly for *nebharo* and *patmiro*. The difference could be because of the small number of experimental animals per treatment (two) used by Shrestha and Pakhrin (1989) and there was also no mention of parturition date, parity or age of the animals, factors that might influence productivity. Furthermore, the use of 3.4 kg day^{-1} of concentrate ration as a basal diet (the ration was composed of 60%, 30%, 7% and 3% of maize flour, rice bran, mustard cake and salt) might have masked the effect of tree fodders on milk yield.

Another factor that might have influence on the discrepancy of perceived quality by *in vivo* experiment from the farmers' ranking could be a difference in the lactation length among experimental animals, since it is reported that butterfat content in the milk of local cows in the early days of lactation is lower than in milk at later stages of lactation. According to Joshi *et al.,* (1992), milk production is highest during the first 12 weeks of lactation. In this experiment, the milk yield in the *khari* and *nebharo* groups of animals was lower and butterfat yield higher than the farmers' rank order and the average lactation period of the cows in these tree species was more than 15 weeks of lactation.

A high level of milk production (3.7 l day^{-1}) at day 0 in the *amliso* group may be associated with the residual effects of the diets offered by farmers before the trial. It may also be due to some genetic influence from exotic animals in the experimental cows. Although, animals in this group were selected as local cows, these cows might have blood of exotic animals also. At Patle, there are large numbers of cross-bred cows and all animals in the *amliso* group were from Patle. Although effort was made best in the selection of lactating cows and tree species, however, the lactating cows for amliso groups became only ready in April, at the time when leaves of amliso were over-mature. Reason of low level of milk production in *amliso group* may be because of the relatively low intake of *amliso* since the leaves were over-mature when the trial was conducted (April). Over-mature leaves of *amliso* are regarded as unpalatable and *kamposilo* to animals (Section 3.6.4).

Harvesting seasons of different tree species varies between locations and even between households within a location, depending on household needs and the knowledge of individual households about tree fodder management (Section 3.7.3). For example, the harvesting season of *tanki* in Ilam is from November to February, while in Dhankuta *tanki* is harvested twice a year, first between October to January and secondly from May to July (Dhakal and Lilleso, 2000). This variation in harvesting period may influence nutrient composition. For example, young leaves are likely to be more nutritious than the leaves at the senescence stage, which will ultimately lead to differences in the nutrition of animals fed on the fodder and hence their productivity. This would be an interesting area for future research to explore such differences. The disparity that the mean difference in milk or butterfat that did not agree with the farmers' ranking could be associated with behaviour of animals and a difference in feeding season. Johansson (1999) reported that feeding during milking has been shown to influence milk production. He reported that feeding during milking resulted in higher milk production and feeding 1.5 hrs before or after milking produced a lower fat yield compared with feeding during milking.

Milk yield and quality depends on diet and many other factors such as the animal's potential for milk production, local management practices and the environment. The impact of tree fodders on milk and butterfat productivity agreed in broad terms with the preference ranking of the farmers, more so for milk yield that farmers could readily observe than for butterfat where observation of the effect of individual fodders was hampered by mixing of milk from different animals. Visible differences in health condition of the experimental animals noted by individual farmers involved in the feeding trials re-enforces the holistic nature of farmers evaluation criteria that may combine productive attributes and health.

Slight discrepancies in ranking of species between the *posilo* quality attributes and the *in-vivo* findings suggest that the local knowledge could be related to the anti-nutritive factors that are present in most fodder trees. Phenolic compounds such as tannins are the most widespread natural anti-nutrients in tree fodders. It would be of interest to investigate how tannin content relates to the farmers' selection criteria of fodder tree species. Selectivity of tree fodders by animals and anti-nutrients is dealt in Chapters 5 and 7 respectively.

4.5 Conclusions

The study clearly showed that there were differences in milk yield and butterfat from different tree species. Tree species such as *badahar (Artocarpus lakoocha)* were clearly better fodders for improving milk and butter fat production in lactating cows. Although *badahar* is known as a potential tree fodder, it is not abundantly available. Better management of *badahar* and other potential tree fodders will help farmers' fodder supply during the critical period of fodder shortage. Other fodder such as *kalobans* is clearly an inferior quality fodder in terms of negative impact on health and productivity of animals. The strong reluctance of farmers to accept the feeding trial on *painyu* (*Prunus cerasoides*) also indicated that local farmers are confident of their perception that the effect of this species would be undesirable to the health and productivity of animals.

Farmers' rankings of tree fodders for *posilopan* agreed with those for milk and butterfat yield. The study revealed that farmers could reasonably differentiate between the 'most *posilo*' (highly nutritious) and 'most *kamposilo*' (least nutritious) fodder species in terms of the productivity of lactating farm animals but that when the differences between species were small, the farmers were less able to consistently distinguish which tree fodders would affect milk yield and quality. In such instances, the local knowledge did not correlate well with animal responses. The understanding however, has given potential scope for appropriate combination of farmers' knowledge with biological based technical data for the improvement of livestock productivity in the hills of Nepal.

CHAPTER 5

INVESTIGATING THE ASSOCIATION BETWEEN PALATABILITY AND THE LOCAL *OBHANOPAN* ATTRIBUTE OF TREE FODDERS

Overview

Characterization of tree leaves by chemical analysis alone can cause over-estimation of their nutritive value, due to the presence of naturally occurring deleterious substances which impede acceptability of tree fodders in animals. This chapter examines the acceptability of tree fodders based on cafeteria trials in ruminant animals and discusses the extent of association between palatability and the locally derived *obhanopan* characteristic that farmers use to select tree fodders. The experiment was conducted in cattle, buffalo and goats under on-farm and on-station conditions in the eastern middle hills of Nepal.

5.1 Introduction

Indigenous fodder trees and shrubs are now receiving increased research attention generally in the tropics and specifically in Nepal (Devkota *et al.*, 1995; Gurung, 2001 and Thapa *et al.*, 1997). In the local fodder evaluation system, farmers consider palatability as an important criterion for assessing fodder tree species (Chapter 3.6).

Both physical and chemical attributes have been reported to influence palatability of tree fodders. Leaf texture, and the presence of spines or thorns are a physical means of reducing palatability of tree leaves (Thapa, 1994; Joshi, 1997). The chemical compounds that have been found to reduce palatability include polyphenolics (tannins), saponins, cyanogens and alkaloids (Cheeke, 1985).

Palatability may, however, vary with the physiology of animals and the organoleptic responses developed by individual animals over time as well as feed availability (Van Soest, 1983). Hodson (1986) reported that the preferences for plant material by animals are greatly influenced by animal behaviour and plant characteristics. Many authors have reported that the presence of tannin, through its astringency and bitterness, reduces palatability, intake and nutritive value considerably (Massdorp *et al.,* 1999; Makkar, 1993; Kumar and Vaithiyanathan, 1990).

Season and availability of other fodder resources are known to influence feed acceptability (Van Soest 1983). Van Soest (1983) reported that if animals are turned into a fresh paddock of a single plant species, the more palatable portions are grazed first and the less desirable later. Hofmann (1989), cited by Alm *et al.* (2002), also reported herbivores eating from previously avoided tannin-rich leaves instead of the usually preferred grass in the season when grass becomes less nutritious. Van Soest (1983) further explained that selectivity could alter as forage supply decreases or if the stocking rate of animals is increased.

Animals may select food based upon their biological need (Alm, 2002), however, according to Arnold (1964) most animals exhibit very little nutritional wisdom and they will select a palatable but poor quality diet in preference to an unpalatable, nutritious diet even to the point of death. They have the ability or desire to select, which may be regulated by the hunger of the animal and the availability of feed. Van Soest (1983) assumed that in general, a hungrier animal is less selective.

Kaitho *et al.* (1997) reported that animals select food by taste, odour, texture and presence or absence of natural toxicants. Hence, identification of the degree of selectivity (palatability) is one of the essential steps in assessing and evaluating the qualities of tree fodders for livestock feeding and for evaluation, promotion and recommendation for fodder tree use.

Conventional methods commonly used to assess preferences of forages include the oesophageal fistula technique, gut content and faecal analysis (Van Soest, 1983) that are laborious, complicated and costly, particularly for developing countries. Alternatively, the relative palatability of tree fodders assessed in cut and carry experiments can be determined by leaf defoliation, grazing observation and dry matter intake data (Faint *et al.*, 1998) or it may be determined by observing free choice consumption of food, allowing animals to sort out the choicest bits as suggested by Van Soest (1983). Direct feeding observations and measurement of fodder intake are convenient and suitable methods for assessing which fodders animals prefer in this kind of study, particularly where trials are to be carried out on farm. Cafeteria trials, where selection is controlled by animal preference, assumes that they select palatable portions first leaving the least desirable parts of the feed unconsumed.

The present study was undertaken using cafeteria trials to explore relationships between the farmers' local *obhanopan* attribute of fodder and animal preferences. The experiment was conducted with cattle, buffalo and goats fed six common tree species that were contrasting in terms of how farmers rated them for *obhanopan* (three were rated *obhano* and three were rated as *chiso*). Quantitative measurements of intake were made twice a day together with two qualitative assessments, observation by researchers of the order that animals ate the fodders and the farmers assessment of animal preference based on their observations of how voraciously animals ate the different fodders.

5.2 Materials and methods

5.2.1 Experimental site

These trials were conducted under both on-farm and on-station conditions with large livestock (cattle and buffalo) and small livestock (goats) at an altitude of between 1200 and 1650 m asl in the eastern middle hills of Nepal. The on-farm experiment was conducted in villages in the vicinity of the Agriculture Research Station (ARS-Station), Pakhribas, Dhankuta.

5.2.1.1 On-station trials

In the on-station trials, eight individuals each of buffalo, cattle and goats were used in the palatability study. The animals were housed in an open-sided shed, placed in individual pens with separate feeders. Each pen was separated by a bamboo-matted partition, which prevented animals from eating the fodder offered to their neighbours. Since these animals had been used for other tree leaf feeding experiments, they were already familiar with the housing and the fodder tree species and acclimatization was not thought necessary. This experiment used six different tree species (Table 5.2) that were commonly available in the eastern middle hills.

2.1.1.1 On-farm trial

The study was conducted with participation of local farmers who expressed an interest in taking part in the feeding trial. The participating farmers by themselves decided on a suitable location for the experiment. This was a central point for all the farmers involved in the palatability experiment. The farmers themselves decided who provided what number of animals and the amount of fodder necessary for the whole experimental period and jointly arranged a suitable venue for the experiment. The experiment was conducted in two terraces belonging to one of the participating farmers.

Plate 5.1 Palatability experiment (on-farm) in progress (another four animals were located on a second adjacent terrace).

Six farmers were involved in the feeding trial and four of them brought two cattle each to the experimental venue for the feeding experiment. Four animals were each tethered on two terraces. A distance was maintained between the animals such that animals were not attracted to each other's fodder. The participating farmers and two support staff were involved in the experiments. Selectivity of animals was monitored as explained in the next section.

5.2.2 Feeding time

The experiment was conducted at 7.30 am in the morning (a time that coincides with the farmers' usual feeding time) and again at 2:30 pm in the afternoon. Between the feeding intervals of the test tree fodders, the animals were allowed to graze under normal feeding or grazing conditions (for about 4-5 hrs) and brought back to the experimental site for the remaining experimental session. The idea behind conducting the experiment in the morning and in the afternoon was to see the animals' preferences when they are hungry, usually in the morning, and full, usually in the afternoon.

5.2.3 Experimental period

The feeding experiments were conducted during February/March at the time local farmers actually practise feeding these tree species. Due to insufficient amount of fodder during February/March, the experiment on buffalo was conducted for two days only, while the experiments on cattle and goats were conducted for four and five days respectively.

5.2.4 Animal numbers

The experiment on cattle and goats was conducted both in on-station and on-farm conditions. The experiment for buffalo was conducted only under on-station conditions because not enough buffalo were available on-farm. The number of animals taking part in the experiment and their duration are shown in Table 5.1.

Table 5.1 Numbers of animals used on particular half days in cafeteria palatability trials of tree fodders in eastern Nepal

Animal	Site	Afternoon (day)					Morning (day)				
		1	2	3	4	5	1	2	3	4	5
Cattle	On-farm	8	8	8	4	-	8	8	8	4	-
	On-station	8	8	-	-	-	8	8	-	-	-
Buffalo	On-farm	-	-	-	-	-	-	-	-	-	-
	On-station	8	8	-	-	-	8	8	-	-	-
Goat	On-farm	8	8	8	8	8	8	8	8	8	8
	On-station	8	8	8	8	8	8	8	8	8	8

5.2.5 Feeding the animals

Branches of tree leaves were lopped according to the farmers' practice; the farmers themselves were involved in the lopping of branches of trees for feeding to the experimental animals. Samples from the fodder trees selected were weighed using a 4 kg spring balance (a balance normally used by chicken traders to obtain the live weight of chickens).

In on-station conditions, the amount of tree fodder weighed was 1 kg each for cattle and buffalo and 500g for goats. Due to the lack of sufficient fodder, the amount of fodder used under on-farm conditions was reduced to 500g and 300g for cattle and goats respectively. The weighed amounts of each tree species were inter-mixed and offered to each experimental animal.

5.2.6 Tree species selected for the palatability experiments

The tree species investigated were limited to those available during the experimental period and as per the decision of the farmers participating in the feeding experiment. Thus the tree fodders identified for the palatability study were *amliso, dudhilo, gogun, malbans, ghotli* and *nebharo* (Table 5.2). These were the most common and abundantly available tree species owned by the participating farmers at the study site. In the on-station trial, *ghotli* fodder was purchased from local farmers, as this species was not available on the farm premises of the station.

Table 5.2. Tree species used in the palatability experiment showing their mean overall *obhanopan* rank score and standard error in brackets (Section 3.5.1). The *obhanopan* position of *ghotli*, not ranked by farmers in the previous research, was allocated using the author's personal experience.

Tree species	Rank score	Scientific name
Malbans	*91.7 (5.98)*	*Bamboosa nutans*
Amliso	*88.9(2.88)*	*Thysolaena maxima*
Ghotli	*NA*	*Sambucus hookeri*
Nebharo	*44.4(8.18)*	*Ficus auriculata*
Gogun	*25.6(4.25)*	*Saurauria nepaulensis*
Dudhilo	*16.1(2.24)*	*Ficus nerrifolia var nemoralis*

5.2.7 Monitoring of the feeding trial

5.2.7.1 Measurement of palatability

The palatability experiment was carried out following modification of the cafeteria trial explained by Van Soest (1983). In this experiment, the tree leaves (including twigs and small branches) from each of the fodder tree species were well intermixed prior to offering to the experimental animals. During the process, the scattered tree leaves were remixed up ensuring that the leaves were not trampled, lost or eaten by neighbouring animals. Each animal was allowed 60 minutes for selection from the mixture. Any left-over fodder was withdrawn and quantitatively recorded. Difference between the left over fodder and the amount of tree fodder offered was calculated as intake of that tree fodder. During each observation, the amount of fodder supplied, the amount of fodder consumed and the amount refused by individual animals was recorded. In addition, researchers' observations of the order that each individual animal ate the fodders and farmers' assessment of animal preferences were recorded.

5.2.7.1.1 Farmers' preference order

Farmers were asked to rank the tree species, from their observation of how each animal ate the different fodders. Their assessments were based on the time spent eating a given tree species, frequency of repeat bites and behaviour of individual animals while eating, such as tail wagging. Each observer reported to an enumerator who was available with a record sheet for each animal. The format of record sheets is shown in Appendix 5.1. The farmers also assisted in collecting and identifying the residual or left over portions of the tree species. They were particularly helpful in identifying the left-over portions of eaten fodders, mainly branches with or without bark, which were often in almost unrecognisable forms.

5.2.7.1.2 Intake order

Records were also made by researchers of when each animal finished eating any particular tree species during the allocated 60 minutes time. The researchers were assisted in this by farmers. Prior to the experiment, the farmers were briefed on how to assist the data recorders. Each farmer was assigned to watch two animals (it was found that farmers got confused when attempting to monitor more than three animals at a time).

5.2.8 Statistical Analysis

The intake data were used to derive a mean morning and afternoon intake of each tree fodder species as a % of what was offered for each animal, by averaging over the whole observation period (two days for buffalo, four days for cattle and five days for goats). The effects of tree fodder species, individual animal and the time of day that feeding took place were then analysed separately for each livestock species and site (on farm or on station) using the general linear model (GLM) procedure in Minitab. Interactions were examined by plotting graphs.

5.3 Results

5.3.1 Intake of tree species by animals

In all cases there was an effect of tree fodder species on intake (p<0.001). Intake of *dudhilo* and *nebharo* was generally high for all livestock species and under both on-farm and on-station conditions. For cattle and buffalo, intake of *ghotli* and *gogun* was consistently lower than other species, while in goats intake of *malbans* was lowest, followed by *ghotli*. (Figure 5.1)

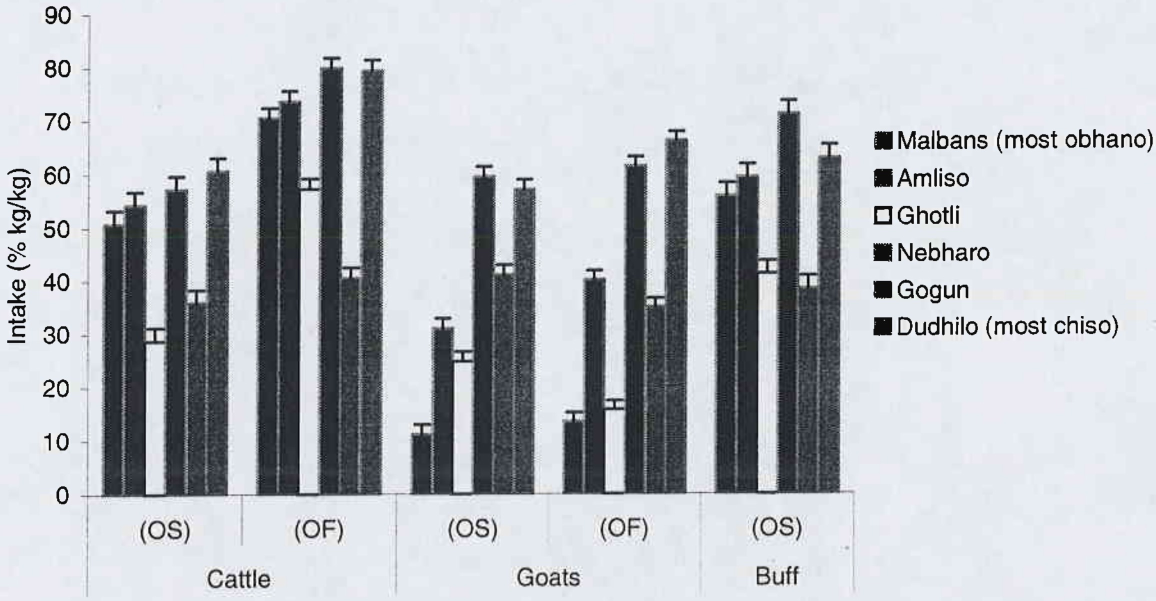


Figure 5.1 Mean intake (% kg/kg of each fodder type) of tree fodders by animals under on-farm (OF) and on-station (OS) conditions (n=16 for each fodder species). Intake data for buffalo is on-station only. Intake was significantly different between tree species for all conditions.

5.3.2 Interaction between tree species and animal

There was a significant interaction between individual animals and tree species under all conditions, indicating that individual animals consumed tree fodders at different rates although the overall pattern of intake amongst tree species described above could still be observed. Figure 5.2 shows the intake for goats on-station as an example of this. Generally there was larger variation in intake among animals under on-farm conditions compared with on-station conditions.

For example, variation in the intake of *amliso* by cattle was from around 45% to 100% under on-farm conditions and about 35% to 65% under on-station condition.

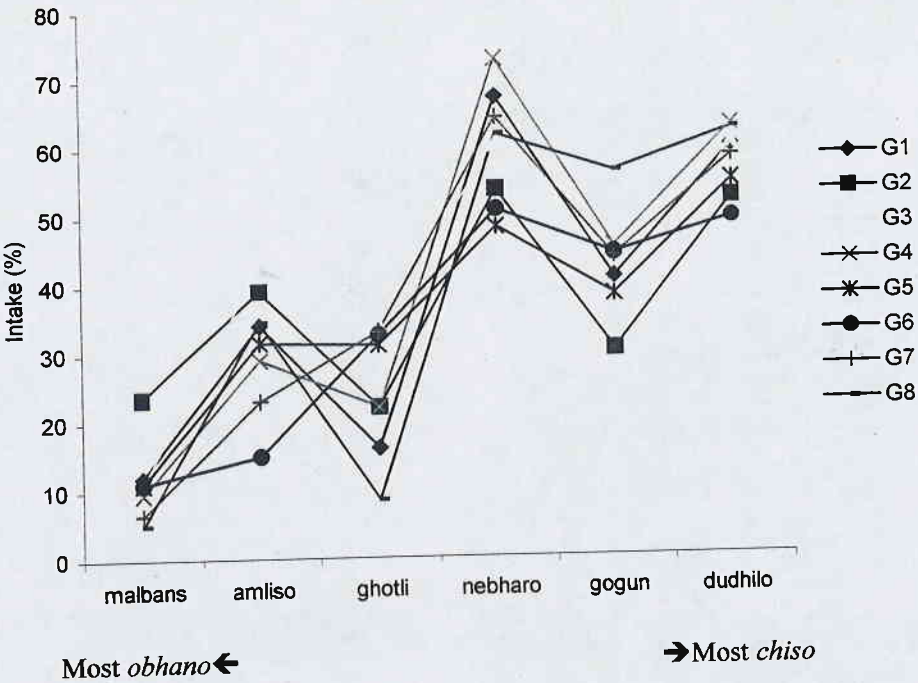


Figure 5.2 Mean intake of different tree fodder species by individual goats under on-station conditions (n=2)

2.1.1 Effect of feeding time on the intake of tree fodders

There was no effect of time of feeding on intake except for cattle under on-station conditions. Here, intake was slightly higher in the afternoon than in the morning (45% vs 51%; p=0.003).

2.1.2 Interaction between tree species and time of day

No interactions between tree species and time of day were evident except for goats under on-farm conditions (p<0.001; Figure 5.3). There was an indication that intake of more *obhanopan* fodders was higher in the morning with intake of *chiso* fodders higher in the afternoon, but intake of *gogun* did not follow this pattern.

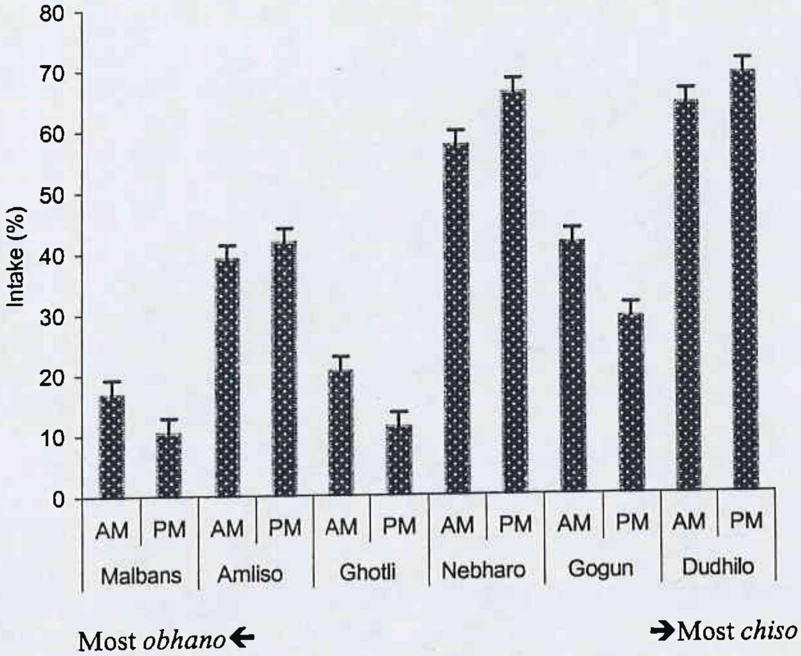


Figure 5.3 Mean intakes of tree fodders by goats (on-farm) during the morning and afternoon (n=8)

5.3.5 Preference order of fodders

Although differences amongst livestock species in order of eating of fodders were evident (Figure 5.1), *dudhilo* and to a lesser extent *nebharo* were generally preferred by all animal types. *Ghotli* (and possibly also *gogun*) were least preferred.

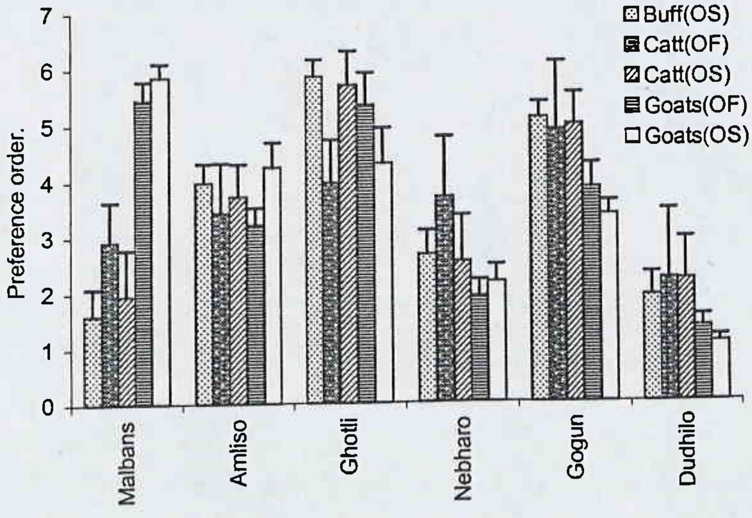


Figure 5.4 Mean preference order that animals were observed to eat tree fodders. Lower numbers represent higher preference. Error bar is the SD.

By contrast, *malbans* was eaten quickly by cattle and buffalo but was the species least preferred by goats (Figure 5.4).

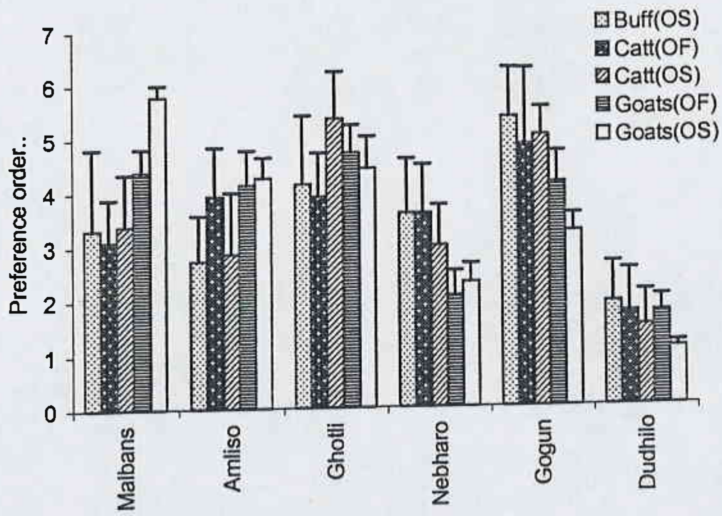


Figure 5.5 Mean preference orders of tree fodders assigned by farmers. Lower the scale higher is the preference order. Error bar is the SD.

The farmers' ranking of animal preference (Figure 5.5) generally agreed with the observation of the order in which the fodders were eaten but overall differences amongst fodder species appeared to be somewhat less pronounced (there were more mean rankings in the range 2 to 5). Within animal species the standard deviation of the preference order was large (>1) for *gogun*, *amliso* and *malbans* particularly in buffalo (on-station), with lower variation among cattle and goats. A difference in mean rank, between farmer ranking and eating order observations, of more than one rank order position was noted for *malbans, amliso* and *ghotli* in buffalo: *malbans* and *amliso* were ranked higher in eating order from observations than their preference order assigned by farmers while *ghotli* was lowest ranked in eating order from observations but not by the farmers. Likewise, for cattle, on-station, *malbans* was ranked higher in eating order by observation than the farmers preference order but lower in goats, on-farm. Full results are shown in Appendix 5.2

5.3.6 Differences in the preference by time of day

When mean rank orders were calculated separately for morning and afternoon, there were few differences. According to farmers, *malbans* was generally preferred more in the morning than in the afternoon (difference >1) by buffalo and cattle whilst the opposite was true for *nebharo* in buffalo (Figure 5.6), although the ranking of eating order did not corroborate either of these observations.

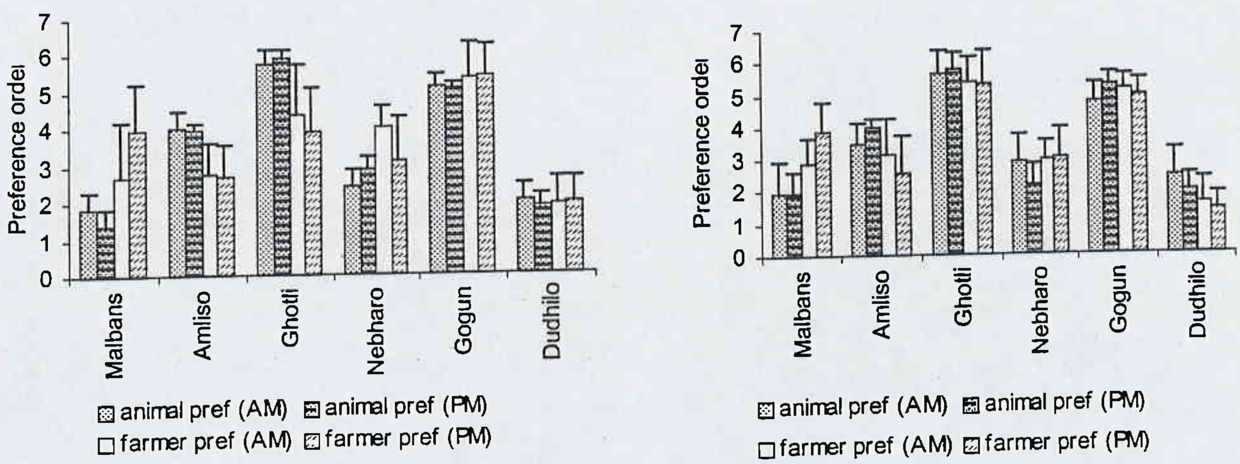


Figure 5.6 Difference between AM and PM on the mean observed eating order of fodders by animals (on-station) and farmers' assignment of animal preference; buffalo (left) and cattle (right). Lower numbers denote higher preference. Error bar is the standard deviation.

In cattle there was slight variation in the preference order of *amliso, nebharo, gogun* and *dudhilo*. Generally *amliso* and *gogun* were more highly preferred in the morning than the afternoon but *nebharo* and *dudhilo* were more highly preferred in the afternoon than the morning.

5.4 Discussion

The observed preference order of animals (their observed eating order) and the preference order assigned by farmers observing the trial generally showed good agreement with measured intake rates. Rank order was not much affected by using a composite parameter calculated by taking a mean value for intake, farmer assigned ranking and observed eating order ranking when compared to single parameters. Initially, another parameter 'frequency of bites' by animals for each test tree fodder was recorded. Alm *et.al.* (2002) employed a similar technique to examine the food choice in fallow deer. But this was discontinued in this trial because it was thought that tree species with higher frequency of bites would not necessarily be the preferred fodder species. This is because the most palatable fodder species would have been continuously eaten by animals without changing to other tree species. The present study suggests that intake alone is a reasonable indicator of animal preferences of fodder tree species. The literature concurs that palatability has a major influence on feed intake in ruminants (Forbes, 1998; Albright, 1993), explaining that intake of tree fodders could be most important parameter to evaluate preference in ruminants. Hadjigeorgiou *et al.* (2003) also estimated forage preference from the relative quantity of forage consumed. Hence, the following discussion on the preference of animals is made based on intake of tree fodders.

Differences between large and small ruminants

Farmers participating in the feeding trials thought that differences in preference of tree leaves between large and small ruminants were related to differences in their tongue textures. They said that the 'rough' tongue of the cattle and buffalo allowed them to graze on coarser and drier leaves than the small ruminants that have a smooth tongue texture. Another factor leading to differences in selection of fodder between these animal types could be related to their gut volumes (Acasio *et al.,* 1999). Because of the larger gut size, the cattle and buffalo graze on fodder irrespective of the fodder quality or the leaf texture. Because of this, the cattle and buffalo in the hills struggle for fodder and may eat any fodder to fill the gut whilst goats with a small gut size find it easier to fill their gut. Goats, which are browsers, are known to be more selective in their choice of fodder compared to cattle and buffalo, which are grazers (Van Soest, 1983, Jasra and Iqbal, 1994). Goats are considered fickle and highly selective in their diets and eat palatable fodder first, whilst cattle and buffalo eat gradually and steadily, and are less selective for fodder type compared to goats (Jasra and Iqbal, 1994). Age might also play an important role in determining forage preference in animals (Abdel-Moneim and Abd-Alla, 1999). However, in the present experiment all the experimental animals were of similar age.

Physico-chemical characteristics

Despite some differences in palatabiltiy amongst tree fodders for large and small ruminants, it was clear that *nebharo* and *dudhilo* were highly palatable for all animal types. The high palatability of these tree species could be because of the soft texture of their leaves. The longer time required to chew coarse leaves such as *malbans* compared to trees which have soft leaves such as *dudhilo* and *nebharo* (Section 6.6) corroborates leaf coarseness as a factor that affects palatability. Various authors (Dahiya *et al.*,1998; Joshi, 1997 and Abdel-Moneim and Abd-Alla,1999) have also reported that palatability is affected by texture and morphological structure of leaves. This appears to apply more to goats than to cattle and buffalo. The cattle and buffalo, although they preferred tree fodders with soft leaves, also ate tree species with coarse leaves such as *malbans* voraciously. Farmers explained that because *malbans* leaves are thin and more *obhano*, goats find it hard to crush them, because of the low volume of saliva produced (by goats) to wet the food mass compared to cattle and buffalo. They also explained that during the process of crushing, the thin and coarse nature of the leaves would hurt the muscles of the mouth causing animals' aversion to such fodder species. They also explained that highly palatable tree species such as *dudhilo* have relatively thick and smooth leaf texture requiring less volume of saliva to wet the food mass. As a result, goats are able to comfortably crush and roll the lump of the crushed leaves of *dudhilo* in the mouth and swallow, which is very difficult in the case of *malbans*. As a result of these difficulties, sheep or goats do not attempt to eat *malbans* until and unless they are hungry or are offered it as a sole choice. It was reported that if *malbans* was offered as a sole fodder, they ate it with much appreciation. This implies that the goats are very selective to feeds if offered them with alternative fodder types. These perceptions of the farmers are consistent with the differences in the physiology and the presence or absence of enzymes present in the digestive systems of the animals. Despite leaf coarseness, *gogun* appeared to be palatable to goats but was least preferred among cattle and buffalo. It appears that the cattle and buffalo generally make no selection based on the texture of tree leaves. Lower preference of *malbans*, *ghotli* and *amliso* by goats indicated that goats have less preference for tree species that are generally coarse and dry. However, looking at the higher intake of the leaves of *gogun* by goats compared to cattle and buffalo, it appears that the preference of tree fodders is not only governed by texture but also by other factors which may include tannins investigated in Chapter 7 and discussed further below.

Obhanopan

Although the intake of tree fodders was similar for all animal types for *chiso* tree fodders, this was not so for *obhano* fodders. Intake was closely associated with *chiso* characteristics of tree fodders in goats in that the more *obhanopan* the fodder the lower the intake. The lower intake of *obhano* fodder by goats may relate to differences in taste among tree species developed by the animals over time, since taste is most influential in directing forage preference in sheep (Krueger *et al.,* 1974). Despite leaf coarseness of *gogun*, its palatability among goats may also be related to its *chisopan* characteristics (2^{nd} in *chisopan* ranking). This concurs fairly well with Abdel-Moneim (1999) who reported that goats tend to select any green fodder (*chiso*) in preference to dry roughage (*obhano* fodders).

Tannins

Animals have different intake preference for different tree species, based on their palatability and local farmers classify fodder into cattle and buffalo fodder and goat and sheep fodder (Thapa, 1994). Because of their abundance in tree leaves, tannins might have influenced palatability to animals of the offered species of trees. *Gogun* has been shown to contain high levels of condensed tannin (Chapter 7.3.4), above the level at which ruminants generally rejected feedstuffs. Kabasa *et al.* (2000) reported that ruminants generally reject feedstuffs containing more than 5% condensed tannins. Perhaps one of the reasons for the difference between goats and cattle and buffalo on the liking and disliking of *gogun* may be associated with the ability of an animal to offset tannin toxicity. Goats are highly flexible in their feeding behaviour and are apparently more tolerant to tannins than other ruminants under similar conditions (Gilboa *et al.*, 1995; Silanikove *et al.*, 1996; Jasra, 1994). Begovic *et al.* 1978 cited by Silanikove *et al.*, (1996) reported that the presence of an enzyme in goat saliva could reduce the tannin astringency that affects palatability. They also reported that the higher activity of microbial tannase in rumen mucosa enables goats to consume large amounts of tannin-rich plant material in comparison with cattle or buffalo.

Lower intake of *gogun* in cattle and buffalo compared to intake in goats and low intake of *ghotli* in cattle, buffalo and goats suggests that there are other factors that influence intake other than those encapsulated by the *obhanopan* attribute. High tannin levels in gogun may explain this while *ghotli* is reported by farmers to be palatable at some stages of leaf maturity, but not when the leaves are over mature. This could be attributed to the presence of polyphenolics such as tannin and lignin, concentrations of which rise with increase in leaf maturity (Makkar, 1986; Provenza, 1995). Provenza (1995) reported an established inverse relationship between tannin levels in forage preference and fodder intake.

Time of day

Often selectivity is influenced by environmental factors and the physiological status of animals (Section 3.6, Kaitho *et al.*, 1997), one can assume that a hungry animal will have little scope for selection and eat any type of fodder to which they have access (Van Soest, 1983). However, observation on the feeding of tree fodders in the morning and afternoon did not quite agree with the farmers understanding that the intake and selectivity of animals will change with their hunger status. They had suggested that in the morning, animals, when they are usually hungry, would eat more and be less selective. In contrast to this, the overall intake of animals was slightly higher in the afternoon than in the morning. A slight difference in the intake (%) and the resultant preference order of tree fodders was not necessarily as a result of hunger or fullness of an animal but could be associated more with the *obhanopan* characteristics of tree species. According to farmers, palatability of tree fodder was associated with climatic conditions so that tree fodder which is more *obhano* had higher intake in the morning (when the weather is relatively cooler) than in the afternoon (when the weather is relatively warmer) and vice versa. This was indicated by the higher intake of *dudhilo* (the most *chiso* fodder) and lower intake of *malbans* (the most *obhano* type of fodder) in the afternoon compared to the morning in animals. However, this was limited only to goats under on-farm conditions, although the qualitative data indicated that cattle generally preferred *amliso* and *gogun* in the morning but *nebharo* and *dudhilo* in the afternoon.

Variability in the preference within animal species

The modest differences evident in farmers' assignment of animal preference, observation of their eating order and intake could be because of the short length of experimental period for buffalo (2 days) compared to either cattle (4 days) or goats (5 days). The intake of individual animals varied over the experimental period. Animals generally do not preferentially eat any fodder which has an unfamiliar taste (Joshi, 1997), suggesting that longer trial length may be desirable for future research. Previous research in sheep and goats for Graminaeae forages has demonstrated that animals' preferences for feeds shift with time over long observation periods (Forbes and Kyriazakis, 1995). Durations of between 2 hrs (Rios *et al.*, 1989) feeding at least 5 days (Salem *et al.*, 1994, Kaitho *et al.*1996 and Van Soest, 1983) have been suggested for cafeteria trials. It is possible that a trial length longer than the present study might have yielded slightly different results.

There was larger variation in the intake rate of tree fodders within animal species for cattle and goats on-farm than on station for *gogun* and *ghotli*. There was also wide variation amongst animals on highly palatable tree fodders (*dudhilo* and *nebharo*) for all on-farm animals and buffalo. These larger variations in the preference orders for tree fodders within the same category of animal species could be due to differences in the eating habits of animals maintained under on-farm and on-station conditions, since the animals with voracious appetites may discriminate less than those which may be finicky eaters with lower demands (Van Soest, 1983). For example, one goat liked *ghotli*, while two other goats liked *gogun* but others did not. On-station animals were maintained entirely under a stall-feeding system with choices of different tree fodders and cut grasses including a concentrate ration. The on-farm animals on the other hand were often loose and able to scavenge and graze on available wastelands and they were brought to the experimental venue from different locations. The variation within on-station buffalo could be because of the short duration of experiments as discussed above.

5.5 Conclusions

Palatability of tree fodder was found to broadly reflect the farmers' *obhanopan* criteria of fodder evaluation. In general, *chiso* tree fodders were more palatable than *obhano* fodders to all categories of animals. *Obhano* tree fodders were less preferred by goats whilst cattle and buffalo showed no obvious preference with regards to *obhanopan* characteristics, although *chiso* fodder was preferred over *obhano* fodder.

Farmers' understanding of a link with temperature and moisture content of fodder leads them to suggest that in cool temperatures animals prefer *obhano* fodder but when warm they prefer *chiso* fodder was not clearly seen in this study, except in the case of goats. However, the present research observed what animals ate when mixed fodder was offered so that *obhano* fodder may have offset *chiso* fodder and vice versa.Trials where intake of predominantly *chiso* or *obhano* fodder were compared in morning and afternoon feeding might yield different results.

Tree fodder production and improvement programmes should include species of both high and low palatability (with good fodder value in other respects) to ensure year-round fodder availability and high animal productivity. Tree fodder that was inherently low in palatability tree might be made acceptable through supplementation with other fodder species, which are highly palatable (Makkar, 1993).

CHAPTER 6

IMPACT OF *ADILOPAN* ATTRIBUTE OF TREE FODDER ON VOLUNTARY INTAKE

Overview

Chapter 5 investigated farmers' knowledge about the *obhanopan* of tree fodders by means of a cafeteria trial in cattle, buffalo and goats and explored how the feeding time and duration of feeding influenced intake and selectivity in animals. This chapter attempts to investigate the biological interpretation of another local fodder quality attribute, '*adilopan*', revealing the importance to farmers of the extent to which tree fodders satisfy animal appetite. Correspondence between *adilopan* and appetite satisfaction are discussed in the light of the behaviour of animals and chemical and textural properties of fodder leaves. This involved feeding trials measuring intake and duration of appetite satisfaction for single tree fodders, as opposed to the mixtures used to ascertain selectivity in Chapter 5.

6.1 INTRODUCTION

As established previously (Section 2.4) fodder trees are an integral part of the diet of ruminants in the hills of Nepal that are increasingly recognized as important suppliers of protein especially during the dry season. In addition to their nutritive value, information on animal behaviour in relation to acceptability of tree fodders, including how much and how fast they are eaten, is important for effective feed planning. It is also important in an early phase of the selection process of trees in deciding which species are most suitable for village planting. *Adilopan* (literal meaning 'duration of appetite satisfaction') is one of the important characteristics of tree fodders considered by Nepalese mid hill farmers in evaluating fodder quality (Section 3.7). This terminology is often found closely associated with *obhanopan* (Section 3.5). To cope with the fodder shortage during the critical dry period, farmers deliberately offer feeds that are known locally to have the ability to satisfy appetite and so extend the duration of appetite satisfaction of animals (Section 3.9.2). Farmers in Kenya have similar strategies for setting priorities for feeding tree fodders during the dry season. According to Roothaert and Franzel (2001), ability of fodder to satisfy hunger is one of the most important criteria used to evaluate fodder quality by farmers in sub-humid zone of Kenya.

Selection and intake of diets depend not only on the available fodder resources but also on the feeding behaviour of the animals (Dicko and Sikena, 1991). Better understanding of feeding behaviour of animals for different fodders may allow the development of management strategies aimed at increased animal production.

Previous research has suggested the need for a sound biological interpretation of farmers' knowledge systems to allow improvement of livestock productivity within the objectives of the farmers (Thorne *et al.,* 1999). This study attempts to identify the biological basis of farmers' knowledge about *adilopan* of tree fodders through a voluntary intake trial. In this trial, feeds were offered to the animals until there was refusal and so was an attempt to assess the *ad libitum* intake of a single feed where choice and selection were eliminated (Van Soest, 1983). Animal behaviour was then observed to measure the duration that the ingested fodder satisfied their appetite. Overall the trial aimed to ascertain the extent to which farmers' tree fodder preferences were reflected in the behaviour of animals and to validate the relationships between the farmers' assessment of fodders in terms of *adilopan* and appetite satisfaction in ruminants.

6.2 Materials and methods

6.2.1 Site and trial period

Two trials were conducted, one on-station and one on-farm. The on-station trial was held at Agriculture Research Station (ARS-Station), Pakhribas, Dhankuta. The animals were housed under a shed and separated by bamboo partitions. The on-farm experiment was conducted in villages in the vicinity of the station. The animals were tethered individually on crop-free *bari* land under the shade of a tree. Each animal received free access to water. The study was conducted for two days during the winter season (when the land remained fallow after crop harvest) and at a time when the farmers actually practise feeding tree fodders as a supplement to a crop residue diet.

6.2.2 Animal numbers and fodder tree species

The fodder tree species selected were those which were available to the farmers at the time of the experiment.

On station, four animals each of cattle, buffaloes and goats were used in the trial with mean live weights (standard deviation in brackets) predicted from girth measurements (Section 2.2.4.4) of 143.7 kg (±28.4), 185.63 kg (±25.8) and 21.4 kg (±0.3) respectively. Six fodders (Table 6.1) were fed to all replicate animals, except that goats were not fed *khasre khanyu* or *malbans*. Each fodder was fed to all replicate animals at the same time with separate feeding periods for each fodder lasting for two days. Buffalos were not available for the on-farm experiment. Numbers of cattle and goats taking part in the on-farm experiment varied with respect to the availability of tree fodders and interest of farmers. In cattle (on-farm), the experiment was conducted for *amliso* (*Thysanolaena maxima), dudhilo (Ficus nerrifolia var nemoralis)*, *malbans* (*Bamboosa nutans)* and *nebharo* (*Ficus auriculata*) with 2, 4, 2 and 6 cattle respectively. In the case of goats (on-farm), the experiment was conducted for *dudhilo* and *nebharo* with four goats. Under on-farm conditions, the average predicted live weights of the cattle and goats were 166.2 ±12.0 kg and 27.7 ±0.5 kg respectively.

The experimental animals under on-station conditions were all males, whilst under on-farm conditions they were non-milking mainly dry and unproductive cows and oxen. The fodder tree species used for the on-station and on-farm trials and their *obhanopan* and *adilopan* rankings are given in Table 6.1.

Table 6.1. *Obhanopan* and *adilopan* rankings (Chapter 3) of the tree fodders used in on-farm and on-station experiments. Figures in brackets are the standard deviation.

Tree species	*Obhanopan*	*Adilopan*
Malbans(Bamboosa nutans)	91.7 (5.98)	90 (5.83)
Amliso(Thysanolaena maxima)	88.9 (2.88)	92.8 (1.53)
Khasre khanyu(F. semicordata var semicordata)	73.9 (3.43)	60 (6.25)
Nebharo (Ficus auriculata)	44.4 (8.18)	62.2 (6.37)
Gogun (Saururia nepalensis)	25.6 (4.25)	35.6 (3.96)
Dudhilo(Ficus nerrifolia var nemoralis)	16.1(2.24)	25 (3.68)

6.2.3 Preparation of feeds

Branches of selected fodder trees were lopped and made ready the night before each feeding period. Next morning, the tree species selected were weighed out using a 4 kg spring balance and divided into several bundles of 3 kg and 1 kg each (including branches). The 3 kg and 1 kg lots were for feeding to the large ruminants (cattle and buffalo) and goats respectively.

6.2.4 Animal behaviour and intake recording

6.2.4.1 Feeding time

To correspond with the farmers' feeding practice, the large ruminants were fed on 1.5kg (approximately 1% live wt) of rice straw the night before commencement of each voluntary feeding trial. The experiment was initiated at 07:00, a time when the farmers begin feeding animals. Weighed lots of tree leaves with branches in bundles were supplied to the experimental animals. Additional fodder was supplied several times until the animals stopped eating completely and there were some refusals. Time at which the animals stopped eating was noted and any refusals were withdrawn. The fodder refusal or 'orts' was carefully collected and then weighed. Difference between the feed supply and feed refusal time was noted for individual animals.

After noting the refusals, activities and behaviour of the individual animals maintained for each fodder tree species were closely monitored for subsequent symptoms of hunger.

6.2.4.2 Monitoring and estimation of the length of time controlling hunger behaviour

During the monitoring exercise, branches of individual fodder trees with leaves were brought in front of the animals every 20 minutes to draw the attention of animals and to observe their symptoms of hunger. The resultant activities of animals related to hunger such as salivation, mooing, tail wagging, heaving and shaking heads towards the tree leaves, objects or animal attendants and restlessness were carefully observed.

Combinations of these behaviours were considered as indications that the animal was hungry. The time at which the animals exhibited symptoms of hunger was noted.

The length of time (minutes) that a fodder controlled the hunger of individual animals was estimated by the difference between the time at which the animals refused eating the offered food and the time the animal exhibited hunger behaviour.

Plate 6.1 Voluntary intake trials on different tree fodders is on progress

2.1 Statistical analysis

The on-farm and on-station data derived from experimental days were averaged for each animal and analysed for variance using the General Linear Model (GLM) procedure in the Minitab statistical program (Minitab for Windows 2000, release 13.31). The effect included in the model was tree species.

6.4 Results

Results of the voluntary intake trials are explained in the following sections. The first results are of on-station trials, followed by presentation of on-farm data.

6.4.1 RESULTS OF ON-STATION TRIAL

6.4.1.1 Fresh and dry intake

Intake by cattle of both fresh matter (p=0.010) and dry matter (p=0.00) varied amongst fodders and generally, iintake of *obhano* fodders such as *malbans, amliso* and *khasre khanyu* were higher than *chiso* species such as *nebharo, gogun and dudhilo* (Figure 6.1). The fresh matter intake varied from a little below 50 g kg^{-1} live wt for *nebharo* to a little over 60 g kg^{-1} live wt for *khasre khanyu* whilst the dry matter intake varied proportionately more from under 15 g kg^{-1} live wt for *nebharo* to approaching double, this for *malbans*.

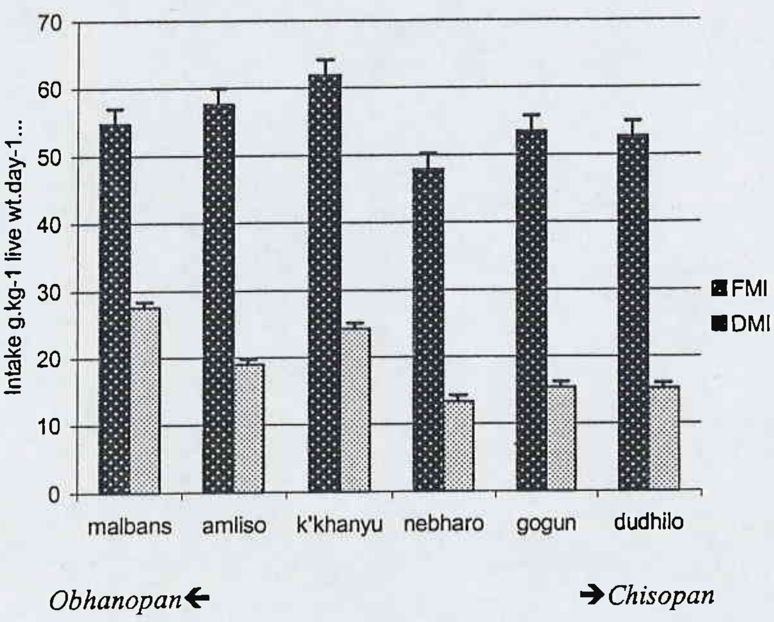
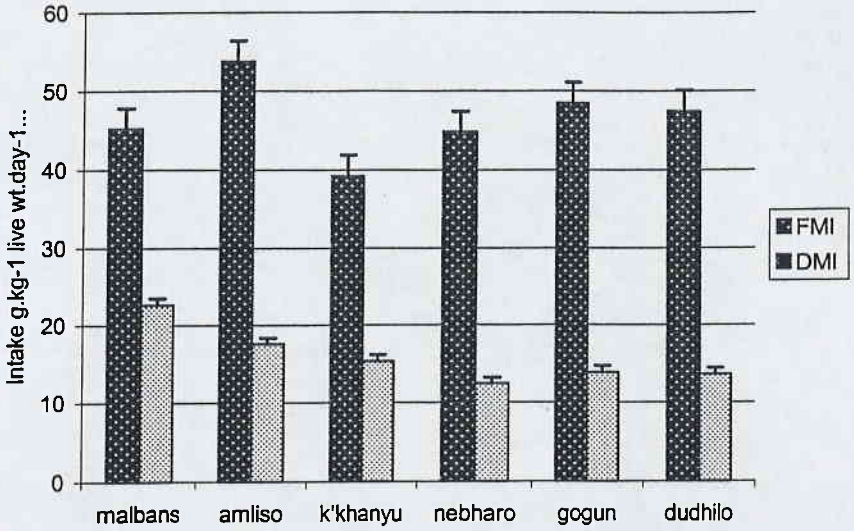


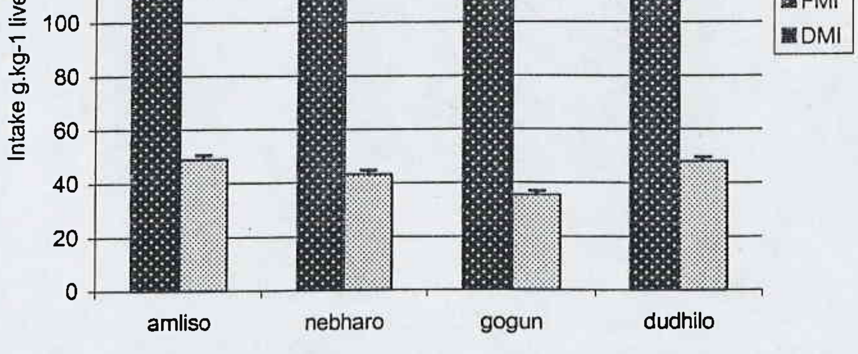
Figure 6.1 Mean daily dry matter and fresh matter intake in cattle (g kg^{-1} live wt), error bars show the SEM; N=8 for all tree species.

In buffalo, both dry and fresh matter intakes were also significantly different amongst tree species (p=0.000 and 0.025 respectively). The range of intake rates were similar in buffalo and cattle the species fresh matter intake varied from about 40 g kg^{-1} live wt for *khasre khanyu* to about 55 g kg^{-1} live wt for *amliso* whilst the dry matter intake varied from about 15 g kg^{-1} live wt for *nebharo* to about 25 g kg^{-1} live wt for *malbans* (Figure 6.2)



Obhanopan← →*Chisopan*

Figure 6.2 Mean daily dry matter and fresh matter intake (g kg^{-1} live wt) (SEM) by buffalo (N=8 for all tree species).



Obhanopan← →*Chisopan*

Figure 6.3 Average dry matter and fresh matter intake (kg day^{-1}) (SEM) by goats (N=8 for all tree species).

Intake of fresh matter and dry matter per unit bodyweight by goats were much higher than for cattle and buffalo and while significantly different amongst tree species at p=0.001 and p=0.000 respectively, there was no clear pattern in relation to *obhanopan* (Figure 6.3). The fresh matter intake varied from about 125 g kg^{-1} live wt for *gogun* to about 165 g kg^{-1} live wt for *dudhilo* whilst the dry matter intake varied from about 35 g kg^{-1} live wt for gogun to about 50 g kg^{-1} live wt for *amliso*.

6.4.1.2 Intake as a proportion of amount offered

There was significant difference between the tree species in fodder eaten as a proportion of the amount of fodder offered (% fresh basis) in cattle (p=0.035) but not in buffalo (p= 0.144) (Figure 6.4).

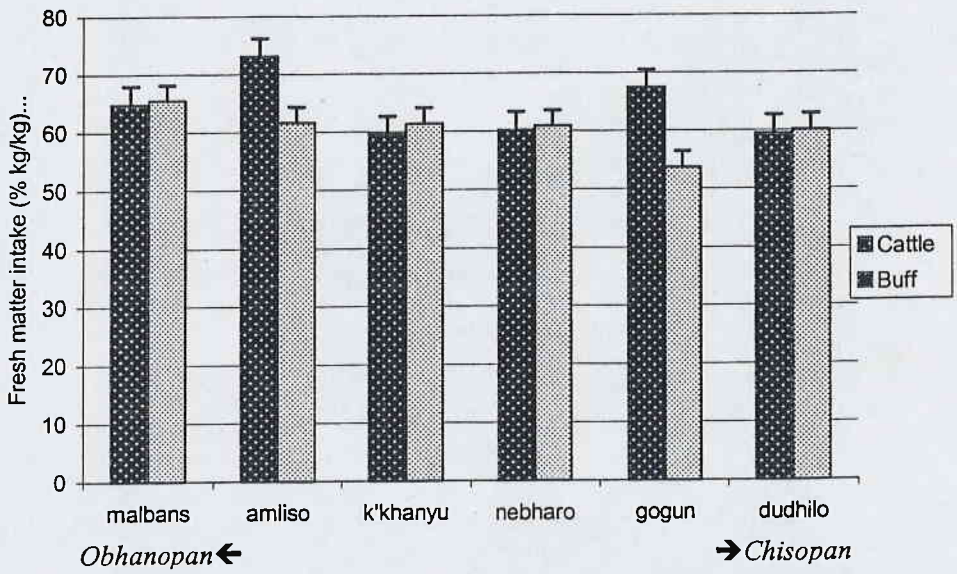


Figure 6.4 Fodder eaten as a proportion of amount supplied (% fresh wt) (SEM) in cattle and buffalo. N is 8 for all tree species.

The proportional intakes of tree species were more or less the same for cattle and buffalo except for *gogun* and *amliso* that were higher in cattle than in buffalo. The intake ranged from about 60% for other tree species to about 70% for *amliso* and *gogun*. In the case of goats, the amount of fodder eaten as a proportion of the amount of fodder supplied (% fresh wt) was significantly different amongst tree species (p=0.005) (Figure 6.5). Intake ranged from about 35% (*gogun*) to about 50% (*dudhilo*).

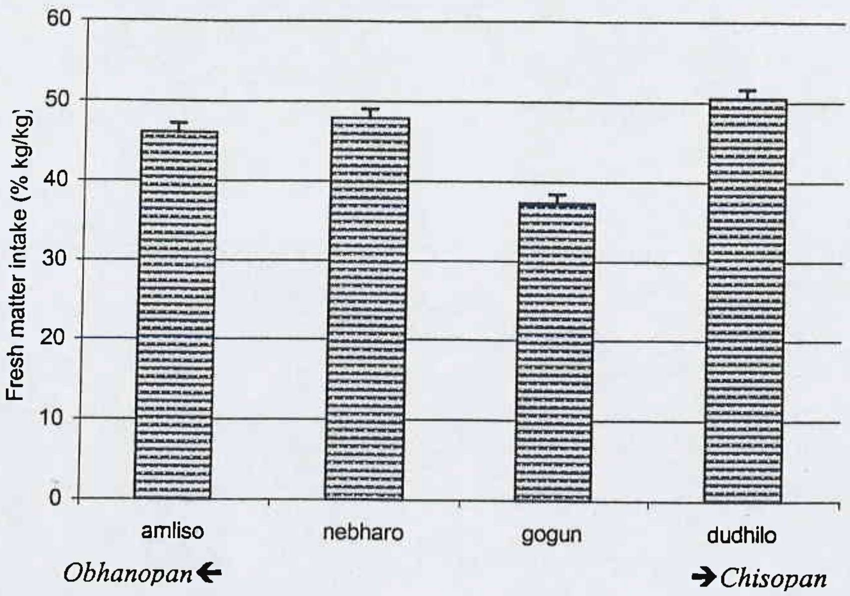


Figure 6.5 Fodder eaten as a proportion of amount supplied (% fresh wt) (SEM) in goats. N is 8 for all tree species.

6.4.1.3 Time taken to eat and duration of appetite satisfaction

There were significant differences in the time taken to consume different tree fodders by cattle (p=0.000). The longest time taken was for *khasre khanyu* (266 minutes) whilst the shortest time (about 170 minutes) was for *dudhilo* (Figure 6.6).

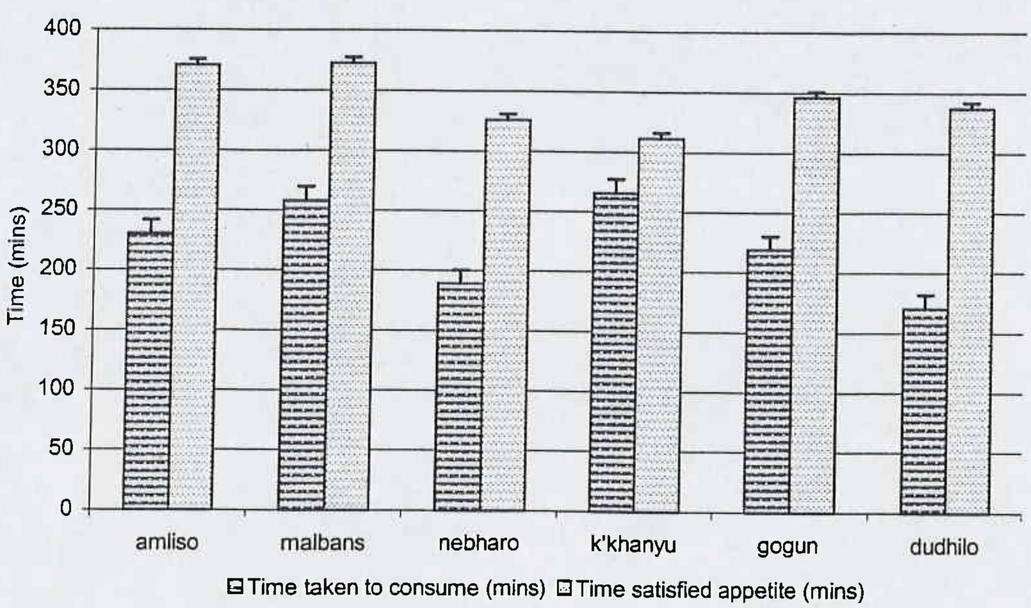


Figure 6.6 Time taken to consume and time for which appetite satisfied (minutes) in cattle (SEM). N is 8 for all tree species.

There were also significant differences amongst tree species in the time for which appetite was satisfied (p=0.000). *Malbans* and *amliso*, both ranked as highly *adilo*, satisfied appetite for the longest time of about 370 minutes whilst *khasre khanyu* satisfied appetite for almost an hour less (312 minutes).

As in cattle, there were significant differences (p=0.000) in the time taken by buffalo to consume different tree fodders (Figure 6.7). The longest time was required to consume *khasre khanyu* (263 minutes) whilst the shortest time was required to consume *dudhilo, nebharo* and *gogun* (180 minutes). There were also significant differences (p=0.000) amongst tree species in the time for which appetite of buffalo was satisfied. *Amliso* satisfied appetite of animals for the longest time of about 380 minutes whilst *nebharo* and *dudhilo* satisfied appetite for almost an hour less (about 325 minutes).

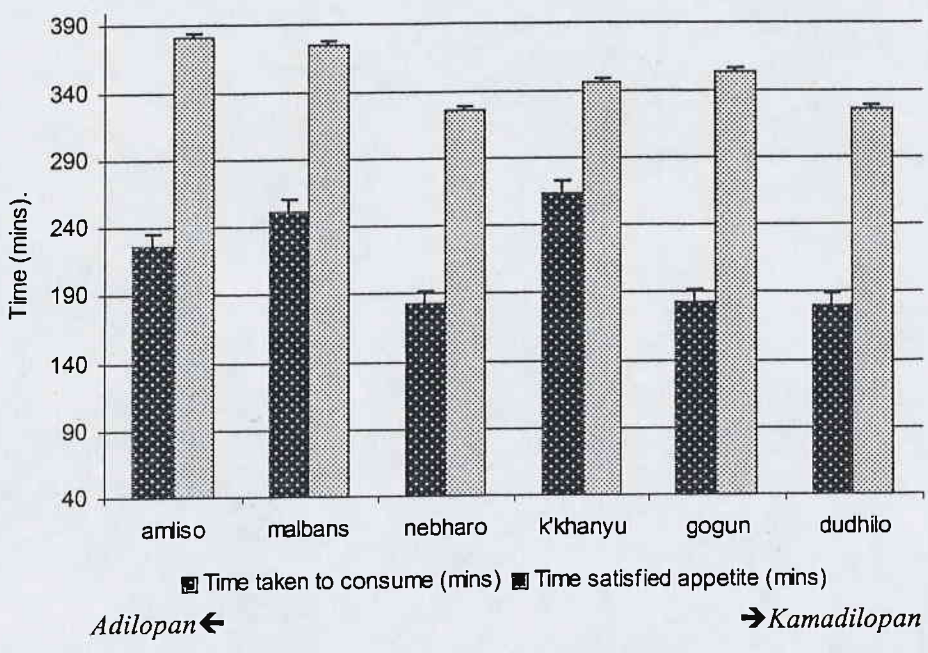


Figure 6.7 Time taken to consume different tree fodders and the time for which appetite was satisfied (minutes) in buffalo. N is 8 for all tree species.

Interaction between tree species and animals (cattle and buffalo) were also examined to see if there were any major differences in intake or appetite satisfaction of different tree species between cattle and buffalo but no marked differences were observed.

There were significant differences in the time taken to consume different tree species by goats (p=0.045). *Amliso* required the longest time to consume (289 minutes) and *nebharo* required the shortest (256 minutes) (Figure 6.8). The time appetite was satisfied for was also significantly different amongst tree species (p=0.000). *Gogun* satisfied the appetite of goats for the longest (228 minutes) and *dudhilo* the shortest (153 minutes).

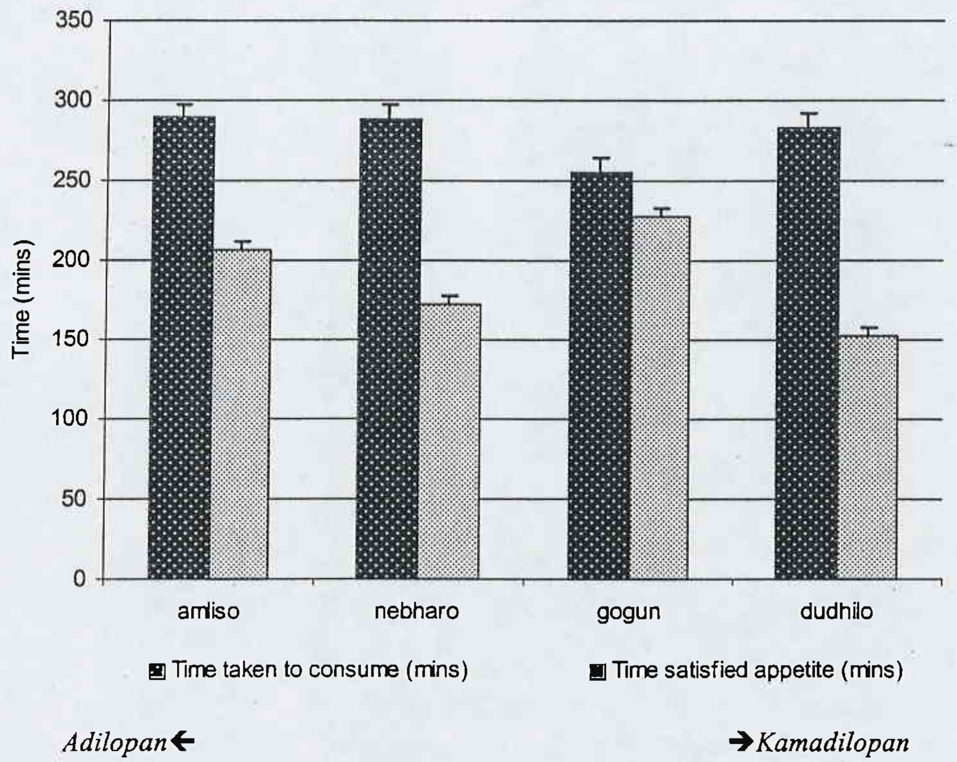


Figure 6.8 Time taken to consume and time for which appetite satisfied (mins) in goats. N is 8 for all tree species.

6.4.2 RESULTS OF ONFARM TRIAL

Under on-farm conditions, the number of animals and tree species was constrained by the availability of tree fodders. In cattle N was 4, 8, 4, and 12 respectively for *amliso, dudhilo, malbans* and *nebharo*. In the case of goats, N was 8 for *dudhilo* and *nebharo*. Results of the on-farm trial were compared with results from the on-station trial. Differences of these results (on-farm results subtracted from on-station) are presented in the following sections.

6.4.2.1 INTAKE OF TREE FODDERS

Dry matter and fresh matter intake (g kg^{-1} live wt) was more or less the same between on-farm and on-station data for cattle (Table 6.2). However, intake of *amliso* (as a proportion of fodder supplied) was higher under on-station conditions than on-farm, whilst intake of *dudhilo* and *nebharo* was higher under on-farm conditions than on-station conditions (Table 6.3).

Table 6.2 Difference in fresh matter and drymatter intake (g kg^{-1} live wt) (on-farm mean subtracted from on-station mean).

	Tree spp	FMI	DMI
Cattle	*Amliso*	-8.2	-2.69
	Dudhilo	7.5	2.14
	Malbans	3.2	1.62
	Nebharo	0.8	0.22
Goats	*Dudhilo*	67.8	19.50
	Nebharo	49.0	13.60

Although fresh and dry matter intake of *dudhilo* and *nebharo* by goats under on-station conditions was higher than intake on-farm (Table 6.2), the intake as a proportion of the amount of fodder supplied (fresh wt basis) was higher in goats under on-farm than under on-station conditions (Table 6.3).

Table 6.3 Difference in the fodder eaten (%) as a proportion of amount of fodder supplied (fresh) (on-farm result subtracted from on-station result).

	Tree spp	Difference (%)
Cattle	*Amliso*	26.1
	Dudhilo	-21.6
	Malbans	5.2
	Nebharo	-17.9
Goats	*Dudhilo*	-19.2
	Nebharo	-24.6

6.4.2.2 TIME TAKEN TO EAT AND SATISFY APPETITE

On-farm cattle generally took a longer time to consume tree fodders than cattle on-station. However, the duration that appetite was satisfied for was longer under on-station than on-farm conditions; this was particularly evident for *dudhilo* (Table 6.4). In the case of goats, both the time to consume and the duration of appetite satisfaction were higher under on-station than on-farm conditions. Under on-station conditions, the longer the consumption time of tree fodders, the longer was the duration of appetite satisfaction (Table 6.4).

Table 6.4 Difference in the time required to consume (mins) and duration of appetite satisfaction (mins) (subtraction of on-farm from on-station result).

	Tree spp	Time taken to consume (mins)	Duration of appetite satisfaction (mins)
Cattle	*amliso*	-50	12
	dudhilo	-85	80
	malbans	-7	1
	nebharo	-39	30
Goats	*dudhilo*	79	24
	nebharo	96	13

6.5 DISCUSSION

Intake of dry matter and fresh matter

Although *chiso* fodders are generally more palatable than *obhano* fodders when the animals are offered choices of fodders (Chapter 5), the higher intake of both dry and fresh matter of *obhano* fodder in animals, particularly in cattle and buffalo, under voluntary feeding suggested that there could be some intrinsic factors in the *chiso* category of tree fodders that have an effect on animals' intake preferences. Above a certain limit, accumulation of such intrinsic factors could possibly trigger, influencing and restraining the animals from excessive intake of these fodder species. Thapa (1994) reported negative effects of *chiso* fodders on the performance of animals causing reduced palatability. Apart from the taste and smell of fodder (Ng'ambi and Kekena-Monare, 1996), one such factor could be the presence of phenolics. Though the concentration of tannin varies with leaf stage and season, there is an established inverse relationship between tannin levels and voluntary intake (Provenza, 1995). *Khasre khanyu* and *amliso* are the tree species containing the highest and lowest levels of total phenolics and tannic acid respectively of a total of 15 different tree fodders studied in Section 7.3.4. This suggests that the intake of tree fodder is possibly associated with the presence of tannin types in them. As discussed in Chapter 5, a longer-term intake trial would be necessary to confirm this.

When the intake of tree fodders as a proportion of amount supplied (fresh weight) was examined, no remarkable difference was found in relation to the *obhanopan* of tree fodders. The slight difference in the intake of *gogun* and *amliso* (in cattle compared to buffalo) and high intake of *dudhilo* and low intake of *gogun* (in goats) do not necessarily suggest acceptability but may reflect the amount of fodder that is not edible to the animals. Large portions of *amliso* that are supplied as fodder have stems and remain uneaten by animals (Section 2.2.5.2.1). The low proportion of intake of *gogun* by buffalo and goats and of *khasre khanyu* in cattle supports this argument. Although *gogun* comes under the *chiso* category, its twigs and young branches are not as palatable as those of *dudhilo* and *nebharo*. Likewise, the leaves of *khasre khanyu* are coarse and dry and become less palatable when feeding is delayed. This tendency for preference for portions of *dudhilo, nebharo* and *khasre khanyu* was observed in animals in the experiment in Chapter 5. A lower intake of tree fodder as a proportion of the total amount supplied in goats compared to cattle and buffalo could also indicate a difference in eating habits of animals. Goats are fickle and generally prefer to alternate between different feeds (Marten and Andersen, 1975). Le Houerou (1991) has also reported that in a study of the intake of native and exotic shrubs offered either alone or in a mixture to ewes, consumption of mixed shrubs was higher than that of a single species.

Adilopan and appetite satisfaction

More *obhano* type of tree fodders generally required a longer time for chewing before there was a refusal compared to more *chiso* types of tree fodders, indicating a possible relationship between the physico-textural properties of the fodder species and how quickly the food gets dissolved in the mastication process in the mouth and swallowing. As expected, fodder species containing higher dry matter content and more *adilo* fodders such as *malbans* and *amliso* satisfied appetite for a longer duration i.e. the animals took longer time before exhibiting symptoms of hunger. These species contained >40% dry matter and have lower rumen degradability (<50%) (Subba 1998; Subba and Singh 2001) than the other tree species studied. Farmers' perception that *adilo* tree fodder satisfies appetite for longer periods than *kamadilo* fodder generally agreed with the current findings. Although *gogun* is locally categorized as a *chiso* type of fodder, it also satisfied appetite at a rate similar to *adilo* fodder species such as *malbans* and *amliso*. Since condensed tannins (Proanthocyanidin) are known to complex protein and other nutrients (Makkar and Becker, 1998., Makkar and Goodchild, 1996), the rate of appetite satisfaction may be attributed to the presence of a higher amount of condensed tannin (Chapter 7) in *gogun* compared to other tree species, particularly *amliso* and *malbans* which contain low tannin (Chapter 7). Thus the presence of condensed tannin may play a role in arresting degradation and delaying reduction of rumen fill.

The longer time for which appetite of animals fed on these fodder species was satisfied could be because of lignin in plant cell walls. Lignin encrusts the cell contents of the plant (Van Soest, 1981), an association that makes digestion more difficult (Baumont *et al.*, 2000) thereby increasing the retention time of the food in the rumen. As a result, the resultant 'digesta load' of the gut perhaps gives animals a feeling of fullness. Except for *khasre khanyu*, there was generally a positive association between the time to consume tree fodders and the time that appetite was satisfied for i.e. the longer the time required to chew, the longer was the appetite satisfaction of animals. Despite the longer time spent in consumption, the relatively shorter duration of appetite satisfaction in *khasre khanyu* indicated that the quantity of edible portion received by animals was small compared to the length of time spent to consume it.

The nature and characteristics of tree fodders in terms of rumen degradability might reflect whether the food is *adilo* (slowly degradable in rumen) or *kamadilo* (quickly degradable in the rumen). According to Ørskov (1998), the important attributes that determine intake include digestion and speed of digestion of the feed i.e. the faster the rate of passage of digesta from the rumen, the higher will be the intake or appetite of the animal for that food. The length of time for which appetite is satisfied could therefore be associated with speed of degradation in the rumen or gas production characteristics of the food, as in *malbans* and *amliso*, which satisfied appetite of animals for longer than *dudhilo* and *nebharo*. This agrees reasonably with the gas production (PD) of *dudhilo* (59%), *nebharo* (44%), *malbans* (41%) and *amliso* (37%) (Section 7.3.4.7), and could be one of the reasons why farmers placed *malbans* and *amliso* as better fodders than *nebharo* and *dudhilo* in their preference ranking (Section 3.5.3). Earlier reports by Thorne *et al.* (1999) of an association between farmers' preference for poorly degradable (*in-vitro*) tree fodders agree well with the present findings. Other reasons for differences in appetite satisfaction could be the physical characteristics of tree fodders such as dryness and resistance to crushing, which could have affected intake rate in animals. Baumont *et al.* (2000) reported that intake of forage plants decreases as plant material ages. One can expect that the decrease in intake of a given tree fodder is the consequence of an increase in its rumen fill effect: in other words, tree fodder with a higher 'rumen fill ability' will show a quicker reduction in feed intake. However, observing the variation in the amount of intake of tree fodders in this study, it appeared that in no case was the intake enough to completely fill the rumen of animals although the fodder was supplied in excess of intake. This suggests that the ingestibility of any tree fodder under sole feeding would not fill the animals completely. This could be because of eating habits of animals, which is based on local feeding system where farmers feed a variety of different fodders. Offering choices to animals may stimulate fodder intake level (Baumont *et al.,* 2000), preventing some toxicity problems (Dicko and Sikena, 1991) and perhaps regulating body nutrition requirements. However, further research would be needed to establish this.

The tree species in the voluntary intake study in cattle and buffaloes were six (*amliso*, *malbans*, *gogun*, *khasre khanyu*, *dudhilo* and *nebharo*). In case of goats, only four tree species were considered in the voluntary intake study (*malbans* and *khasre khanyu* were only occasionally nibbled but not completely eaten by goats so these species were withdrawn from the study). Tree leaves were already dry and dehydrated at the time they were fed (tree fodders were lopped a day prior to feeding). Because the leaves were dry (i.e. the leaves were very *obhano*) and in some cases coarse (*khasre khanyu*), only a few tips were eaten by animals and then only in the morning time, when rate of leaf dehydration could be low because of low solar radiation. Association of palatability and textural properties of tree fodders have already been discussed in Chapter 5.

Variation between on-farm and on-station results

There was more or less similar intake (dry matter and fresh matter intake) between on-farm and on-station cattle. The higher intake of *amliso* (as a proportion of fodder supplied) but lower intake of *dudhilo* and *nebharo* by cattle on-station compared to on-farm conditions could be due to the difference in the amount of fodder supplied to the animals. The higher intake of both fresh and dry matter by on-station goats compared to on-farm goats reflected the difference in the feeding and management systems between these two conditions. On-station goats are limited to the supply of certain tree fodders available on the premises, whilst the on-farm goats are supplied with various types of forages, forest fodders and household wastes. However, as the on-farm trial was limited to only two species of tree fodders, it is necessary to experiment on more number of trees and animals for firm expectation.

Besides a difference in feeding and management, differences in intake could also be related with the origin of the animals. Since the animals for the on-farm trial were brought to a trial site from different locations with diverse feeding and management systems, they could have difference in the appetite and preference for tree fodder whilst the on-station animals are under a more controlled environment.

6.6 CONCLUSIONS

Under sole feeding, intake of *obhano* fodders was higher than *chiso* fodders. There was generally a positive association between the time taken to consume tree fodders and the time for which appetite of animals was satisfied so that the longer the time required to chew, the longer was the appetite satisfied.

It can be concluded that farmers' perceptions about *adilopan* generally agreed with the present findings that *adilo* fodders such as *malbans* and *amliso*, which were often also classified as *obhano*, satisfied appetite for longer than *kamadilo* tree fodders such as *nebharo* and *dudhilo*. However, the fact that *gogun* was classified as a *chiso* tree fodder but satisfied appetite at a rate similar to *obhano* fodders, demonstrates a clear distinction between appetite satisfaction described using the *adilo* descriptor and consumption rate and dung quality referred to using the *obhan*o descriptor. This is an important distinction for targeting and communicating research aimed at helping farmers make efficient use of tree fodders during the dry season.

CHAPTER 7

RELATIONSHIP AMONGST *POSILOPAN*, *ADILOPAN*, TANNINS, PROTEINS AND *IN-VITRO* GAS PRODUCTION

Overview

This chapter investigates how farmers' locally derived *posilopan* attribute of tree fodder is related to proteins and associated tannins that may act as anti-nutritive constituents of fodders that may affect how protein is utilised by ruminants. Also, gas production characteristics of different fodders were measured and used to further explore the locally derived *adilopan* attribute of tree fodders and how this is influenced by anti-nutritive factors. Seasonal distribution of nutrients and anti-nutrients and how they influence farmers' evaluation of the *posilopan* attribute of tree fodders are discussed. Opportunities to improve acceptability and availability of nutrients in tree fodders for dry season feeding are then explored.

7.1 Introduction

Trees are an important nutrient resource during the dry season. However, because of naturally occurring plant toxicants particularly polyphenolics (tannins), their extensive use as a potential source of fodder is limited (Makkar and Becker, 1998). Farmers in Nepal maintain and manage tree fodders in their farmland according to the products they require and the perceived value of the tree species concerned (Thapa, 1994; Joshi, 1997). Farmers' selection of tree species is related with their practical experience of feeding trees and the resultant visible impacts on the performance of their animals (Section 3.7.2). With knowledge specific to individual tree species, local farmers plan feeding strategies according to season and the class and productivity of animals. For example *posilo* (nutritious) fodders are preferably given to lactating cows and growing animals while *adilo* fodders, that are thought to satisfy appetite for a long time, are fed to draught animals and unproductive animals. In a previous study, Thorne *et al.* (1999) reported that farmers might feed *obhano* fodder to control the behaviour of animals.

Some tree species that are known to cause toxicity to animals when their leaves are young are avoided during March/April when the leaves are young and their effects on animals are severe (for example *rato siris* and *gayo*). The leaves of these species are reported to change in their palatability and feeding quality as the maturity of the leaves progresses (for example *khasre khanyu*, *patmiro* and *ghotli*) whilst, others were reported to remain nutritious and palatable at all times (for example *malbans*, *amliso* and *badahar*). Farmers also identify palatability of tree leaves related to seasonal changes in leaf bitterness. According to Thapa, (1994) Solma farmers reported that both immature and over mature leaves are associated with leaf bitterness. In general many farmers reported that palatability of tree fodder is associated with leaf bitterness. They often classify bitter fodders as suitable for small ruminants (goats and sheep) but not large ruminants (cattle and buffalo). It is generally held scientifically that leaf bitterness is associated with tannins (Makkar *et al.*, 1987; Kumar and Vaithiyanathan, 1990). Although some tree species contain bitter principles such as alkaloids and glycosides such as saponins and cyanogens (Cheeke, 1985), only tannins have been considered in this study due to their abundance in trees (Makkar, 1993; Mueller-Harvey, 1989) and significance in animal nutrition research. Tannins such as condensed ones (proantocyanidins) at moderate levels in some feeds are advantageous to ruminants, as they can protect protein from rumen degradation (Maasdorp *et al.,*1999; Van Soest., 1994). However, high levels of condensed tannins may make protein unavailable for post rumen absorption (Makkar and Goodchild, 1996; Mueller-Harvey, 1989) and it is widely believed that tannins influence voluntary intake and palatability of tree fodders (Mueller-Harvey, 1989; Jung and Fahey, 1983) and cause post –absorptive effects (Makkar, 1993). Since, farmers' evaluation of the quality of fodder is based on their perception on the performances of their animals, it is likely that they might have considered these factors in their evaluation system.

This chapter examines the scientific basis of *posilopan*, the most important attribute describing fodder quality of the farmers, through exploration of the possible relationships among tannins (condensed and hydrolysable), crude protein (and its fractionates) and dry matter digestibility. Another, important descriptor of the quality of tree fodder, *adilopan*, is also examined for its possible relationship with gas production, an assay that incorporates inhibitory effects of tannins on degradability.

7.2 Materials and methods

7.2.1 Selection of trees

The selection of tree species was based on the most commonly available tree species being used by the farm households in the eastern mid hills (Section 3.2.1.3). From the five sites described in Chapter 2, two sites, Fakchamara and Patle, were chosen for this study (descriptions of the sites are in Section 2.2.1) to encompass the range of conditions encountered. These sites vary in their accessibility to roads, agroecology, livestock feeding and management systems and their production potential and exposure to interventions by research and development efforts.

Patle was accessible to roads, had more sunshine hours, and a high production potential. Animals in Patle were mostly stall-fed and there were more interventions by research and development activities. On the other hand, Fakchamara had poor accessibility to roads; fewer sunshine hours, low production potential, and animals were mainly grazed and there was little intervention by research and development activities. The sampling areas in both the sites covered mid hills between 1400 m to 1600 m only.

While selecting trees, the following criteria were taken into consideration: age of the tree, management and health of trees. In other words, the selected trees were of the age between 10 and 20 years old. The trees were being used to feed animals and were apparently healthy.

2.1.1.1 Collection of leaf samples

Leaf samples were collected from the mid canopy on all four sides and from the top of the tree. The samples collected from all the sides were bulked. A representative sub-sample of approximately 500g was collected. The collected fresh samples were weighed, enclosed in polythene bags, labelled and brought to the laboratory as soon as possible. Leaf samples of individual trees were taken excluding petioles. Samples were collected from each tree species every month from mid Nov until mid June, that covered the actual seasons of feeding tree leaves to animals.

Table 7.1. Flushing and main lopping periods of the tree fodders sampled in the present study

Local name	Latin name	Bhadra	Asoj	Kartik	Mangsir	Poush	Magh	Falgun	Chaitra	Baisakh	Jestha
Malbans	*Bamboosa nutans*										
Badahar	*Artocarpus lakoocha*										
Amliso	*Thysolaena maxima*										
Khasre khanyu	*Ficus semicordata var semiccordata*										
Nebharo	*Ficus auriculata*										
Patmiro	*Litsea monopotela*										
Rai khanyu	*Ficus semicordata var Montana*										
Chuletro	*Brassiopsis hainla*										
Dudhilo	*Ficus nerrifolia*	1st lopping					2nd lopping				
Tanki	*Bauhinia purpurea*										
Kabro	*Ficus lacor*										
Rato siris	*Albizia julibrissin*										
Painyu	*Prunus cerasoides*										
Gogun	*Sauruia nepalensis*										
Bhimsenpati	*Bridleja asiatica*										

Keys:
Pink shade: Flushing period
Dark shade: Main lopping period
Purple shade: Optional

Nepali month and equivalent English Months

Bhadra=mid Aug-mid Sept, *Asoj* = mid Sept-mid Oct, *Kartik*=mid Oct-mid Nov, *Mangsir*=mid Nov-mid Dec, *Poush*=mid Dec-mid Jan, *Magh*=mid Jan-mid Feb, *Falgun*=mid Feb-mid March, *Chaitra*=mid Mar-mid Apr, *Baisakh*=mid Apr-mid May, *Jestha*= mid May-mid June

The samples were collected every month from *Kartik* (mid Nov/mid Dec) to *Baisakh* (mid May/mid June). These are the seasons at which the leaves from these trees are actually being fed to animals.

Due to the difference in flushing time of some trees and different lopping management practiced by individual farms, there were no leaves for some species of trees during the collection periods. Thus some months were combined and made into three major seasons i.e. season 1 (*mid Nov to mid Jan*), season 2 (*mid Jan to mid March*) and season 3 (mid March-Mid June) so that the data could become analysable.

Flushing and main lopping periods of the tree fodders taken in the study are given in Table 7.1 with their local and scientific names. The samples were collected from mid November to mid June. With exception of *painyu*, these are the major periods for their use as fodder. The shaded boxes in the table indicated the season at which samples were collected.

7.2.1.1.1 Pre-treatment of samples

Upon receiving fresh samples, the leaves were cleaned for any visible surface contaminants e.g. pest eggs, bird droppings, dusts and soil deposits in the field. In the laboratory, the contaminated leaves were washed under running tap water followed by rinsing with distilled water.

7.2.1.2 Sample preparation

In the lab, the leaves were chopped and dried at 60 ± 3°C in a forced hot air oven to a constant weight and the dry matter was determined. The dried samples were ground to pass through a 1 mm mesh sieve for the determination of crude protein, the detergent fibres, detergent nitrogen, tannins and gas production assays.

7.2.2 Chemical analyses

Detergent was used to partition crude protein into fractions that vary in their digestibility and availability in the rumen.

7.2.2.1 Crude protein

Crude protein (N*6.25) was calculated according to conventional technique (AOAC, 1981).

7.2.2.2 Detergent nitrogen

Acid Detergent Insoluble Nitrogen estimates cell wall nitrogen (ADIN, sometimes called ADFN*),* a bound protein that is indigestible and poorly digested by animals (Van Soest, 1994) and Neutral Detergent Insoluble Nitrogen (NDIN) estimates the amount of cell wall protein or insoluble but digestible protein (Van Soest, 1994), were estimated according to Van Soest and Robertson (1985) except that ethanol (dehydrated alcohol) was used to delipidify and dehydrate the fibre digesta instead of acetone.

The crude protein (CP = N*6.25) was estimated spectrometrically (Spectronic $20D^+$, Milton Roy, USA) according to AOAC (1980). The *soluble protein* (SP) and *insoluble but available protein* (IAP) were calculated as the difference of *CP and ADIN*, and *NDIN and ADIN* respectively. The total available protein (TAP) is the sum of soluble protein (SP) and insoluble but available protein (IAP).

7.2.3 Measurement of total phenols, non-tannin phenols and condensed tannins

Total tannins, phenolics and condensed tannins were determined as described by Makkar and Goodchild (1996). Extraction of tannins: Aqueous acetone (70% acetone) was used to extract tannins from 200 mg of finely ground (100 μm mesh) dry leaf samples. Instead of ultrasonic treatment, the samples in solvents were subjected to vortex mixing. To ensure tannins were not inactivated, every minute of mixing, the tubes were dipped in ice-cold water. The samples waiting for vortex mixing or centrifugation were kept in ice-cold water. Analytical methods for each parameter are briefly presented as follows.

7.2.3.1 Analysis of total phenolics

A suitable aliquot (500μl) of the tannin-containing extract was pippeted in test tubes, and the volume made to 1.00ml with distilled water, 0.50ml of Folin ciocalteu reagent (1N) and 2.50ml of the Sodium carbonate reagent (20%). Tannic acid (E. Merck) solution (0.5mg/ml) was freshly prepared as tannic acid standard. The samples and standards were recorded at 725 nm. The total phenolic content (A) was expressed on a drymatter basis.

7.2.3.2 Analysis of total tannin contents

Total tannin content was measured by binding the tannins with Polyvinyl polypyrrolidone[16] (PVPP) (Sigma P 6755). 100mg of PVPP containing test tubes, 1 ml of distilled water and 1 ml of tannin containing extract was added and vortexed. The tubes were then centrifuged at 3000g for 10 mins. The simple phenolics were measured as per the analysis of total phenols (above). The content of non-tannin phenols were expressed on a drymatter basis (B).

Tannins (%) as tannic acid equivalent was calculated by the difference between total phenolic content and non-tannin phenols (i.e. A-B, above).

[16] Polyvinylpolypyrrolidone (PVPP) has a high affinity for tannins. This method assumes that the phenolics, which bind to proteins, are the same as those bind to PVPP (Makkar and Goodchild, 1996)

7.2.3.3 Colorimetric determination of condensed tannins (proanthocyanidins)

The method is based on the fact that proanthocyanidins are oxidatively depolymerised in a butanol-HCl mixture into Anthocyanidins (Makkar and Goodchild, 1996). In a 0.50ml of tannin extract (diluted with 70% acetone), 3ml of butanol-HCl reagent (95:5 v/v) and 0.1 ml Ferric reagent (2% Ferric ammonium sulphate in 2N HCl) were added. Where appropriate, pigments of some leaves were first removed by extraction with petroleum ether containing 1% acetic acid).

The tubes were heated in a heating block at 98±2 °C for 1 hr. Absorbance was recorded at 550nm, the absorbance read in presence of ferric reagent at 550nm using a spectrophotometer (Spectronic, $20D^+$ Milton Roy Company, USA). Condensed tannins (% drymatter) as leucocyanidin equivalent was calculated by the relationships:

$A550_{nm}$*78.26*dilution factor)/%DM. This formula assumes that the effective $E^{1\%,\ 1cm,}{}_{550nm}$ of leucocyanidin is 460.

7.2.3.4 Total extractable polyphenolics

This was determined by using Folin and Denis reagent as per the modification by Anderson and Ingram (1989). The standard tannic acid (E. Merck) was 0.1 mg/ml. Samples were taken at two weights 0.25g and 0.75g and measured in duplicate. 20ml of distilled water, 2.5ml Folin & Denis reagent, 10ml of sodium carbonate (17%) were added to a 50ml volumetric flask containing, 1 ml of standard, unknown and blanks, and the volume made up to 50ml. Measurements were made at 760nm. The total extractable polyphenolics was calculated as:

Total extractable polyphenolics (%) = (Corrected concentration*5)/W

7.2.3.5 In-vitro gas production assays

Gas production was determined as described by Menke *et al.* (1979). Polyvinyl polypyrrolidone, (PVPP, Sigma P6755) were used as phenolic binders at MLURI and ARS-P respectively. Feed samples (200mg) without or with (200mg) PVPP were incubated in graduated 100ml syringes containing 30ml of a mixture of rumen liquor and buffer. The rumen liquor was collected in the morning before the morning feed from three intact male buffaloes. The liquor was collected at equal volume and transported in a thermos. The fresh liquor was stirred and filtered through two layers of muslin. The filtered liquor was bubbled with CO_2 for 1 min. The liquor and buffer was mixed at 1:2 (pH of rumen liquor : buffer mixture) and pH adjusted to about 7. The sample was incubated in a waterbath at 39±0.1 °C, shaking syringes gently 30 minutes after the start of incubation and every hour during the 8-10 hr of incubation. Gas production from the sample was corrected by subtracting the volume of gas produced from the blank.

Analyses were carried out in duplicate. The syringes were incubated at 4, 8, 16, 24, 48, 72 and 96 hrs of incubation. At the end cumulative gas production was calculated for different hours of incubation. The results of the gas volume readings (means of duplicate runs) were fitted to the exponential equation of the form:

$P=a + b\,(1-e^{-ct})$ (Ørskov and McDonald, 1979),

where 'p' represents gas production at time 't', 'a+b' is the potential gas production (PD), 'a' is the rapidly degradable fraction at time zero and 'b' the slowly degradable fraction and 'c' is the rate of degradation per hour and 't' is the time of incubation. The equation was fitted following the software developed by Chen, (1995).

7.2.4 Statistical analysis

Data were analysed using Minitab version 13.1. The effects included in the general linear model (GLM) were season, tree species and site. For site and tree species, p value was derived by user specified tests using adjusted sum of squares for site and tree species. The error term used was site*tree species.

Due to insufficient samples of *painyu* (data was available only for mid March to mid May), *painyu* was excluded from the analysis. For data analysis, the results of monthly analysis of the tree leaves were grouped into 3 main seasons, season 1 (*mid Nov to mid Jan*), season 2 (*mid Jan to mid March*) and season 3 (mid March-Mid June).

Relationships between farmers' rank orders (%) and the chemical parameters were analysed by regression analysis using Microsoft Excel. The linear trend line was plotted (at zero intercept) to derive linear relationships between rank orders (%) and chemical parameters using Excel.

Data from the gas production analysis were also analysed using Minitab. For the analysis, the effects included in the GLM were site, treatment, tree species and season for variables (gas production factors) (a, b, c and PD). For site and treatment, p value was derived by user specified tests using adjusted sum of squares for site and treatment. The error term used was site*treatment.

7.3 Results

7.3.1 Crude protein

There was significant differences between tree species (p=0.000) in the content of crude protein and the level was significantly affected by season (p=0.008). There was significant interaction between tree species and season (p=0.034), this shows that crude protein content changes with season but not in the same way for all species. The CP content of *rato siris* was the highest, but was only significantly higher than the CP content of *rai khanyu*, *patmiro*, *nebharo*, *khasre khanyu*, *kabro* and *chuletro*. The CP content of *gogun* was the lowest but only significantly lower than the CP content of *dudhilo*, *malbans*, *rato siris*, *bhimsenpati* and *tanki*. Although, *rato siris* was the species containing the highest level of protein among the trees, farmers placed this species at 6th position and below *malbans*, *badahar*, *amliso*, *nebharo* and *rai khanyu*. Results of analysis of crude protein and its fractions are presented in Table 7.2.

Table 7.2: Protein and its fractions in tree leaves. Results are expressed on % DM basis. The tree species are in ascending rank order from most *posilo* (*malbans*) to most *kamposilo* (*bhimsenpati*). Figures in brackets are the SEM.

Tree species[1]	C. Protein	Sol. Protein	Total Avail P	ADIN	IAP	AP[1]/100g CP
Malbans	13.9 (0.441)	12.4 (0.446)	13.8 (0.487)	1.5 (0.090)	1.4 (0.117)	98.8 (1.784)
Badahar	11.6 (0.441)	9.7 (0.446)	11.3 (0.487)	1.9 (0.090)	1.6 (0.117)	97.2 (2.007)
Amliso	10.6 (0.689)	9.0 (0.696)	10.3 (0.760)	1.6 (0.141)	1.3 (0.183)	97.3 (1.784)
Nebharo	10.8 (0.441)	8.5 (0.446)	9.8 (0.487)	2.3 (0.090)	1.3 (0.117	90.0 (1.921)
Rai khanyu	9.6 (0.579)	7.5 (0.586)	8.5 (0.639)	2.1 (0.119)	1.0 (0.154)	89.0 (1.784)
Rato siris	16.2 (0.441)	13.4 (0.446)	14.8 (0.487)	2.8 (0.090)	1.4 (0.117)	91.1 (2.786)
Kabro	9.1 (0.496)	7.1 (0.502)	8.3 (0.548)	2.0 (0.102)	1.1 (0.132)	90.4 (3.368)
Tanki	13.4 (0.833)	11.5 (0.842)	12.9 (0.919)	1.9 (0.171)	1.3 (0.221)	95.5 (2.007)
Patmiro	10.4 (0.689)	8.1 (0.696)	9.3 (0.760)	2.3 (0.141)	1.2 (0.183)	88.8 (1.784)
Dudhilo	12.7 (0.441)	10.5 (0.446)	11.7 (0.487)	2.2 (0.090)	1.2 (0.117)	91.8 (2.343)
Khasre khanyu	9.7 (0.475)	7.7 (0.480)	8.8 (0.524)	1.9 (0.097)	1.1 (0.126)	90.5 (1.784)
Chuletro	7.8 (0.441)	5.9 (0.446)	6.8 (0.487)	1.9 (0.095)	0.9 (0.117)	86.1(2.786)
Gogun	7.7 (0.496)	5.7 (0.502)	6.6 (0.548)	2.0 (0.102)	0.9 (0.132)	84.3 (1.784)
Bhimsenpati	12.7 (0.441)	10.7 (0.446)	12.0 (0.487)	2.0 (0.090)	1.3 (0.117)	94.6 (1.784)

[1] Calculated as the available protein per 100g of crude protein

7.3.2 Fractions of crude protein

The soluble protein (SP) was found to be significantly different between tree species (p=0.000). The solubility of protein was significantly affected by season (p=0.007) and there was significant interaction between tree species and the season (p=0.032). The solubility of protein was not affected by farm site and also there was no interaction between site and tree species. The SP in *rato siris* was the highest among the tree species and was significantly higher than the SP content of *patmiro*, *nebharo*, *chuletro*, *gogun*, *kabro*, *rai khanyu* and *khasre khanyu*. *Gogun* was found to be the tree species that contained the lowest amount of SP. The SP in *gogun* was significantly lower than the levels in *bhimsenpati*, *dudhilo*, *malbans*, *tanki* and *rato siris*.

The total available protein (TAP) was significantly different between tree species (p=0.000) and season (p=0.033). There was significant interaction between tree species and the season (p=0.038). The TAP was the highest in *rato siris* and was significantly higher than *rai khanyu, patmiro, khasre khanyu, kabro, gogun* and *chuletro*. The TAP was the lowest in *gogun* and was significantly lower than the level in *tanki, rato siris*, *malbans*, *dudhilo*, *bhimsenpati* and *badahar*.

There were significant differences amongst tree species in the concentration of (Acid detergent insoluble nitrogen) (ADIN) (p=0.001). All other variables were not affected by site or season and also there was no interaction between tree species and site or season. The highest level of ADIN was found in *rato siris*, but it was only significantly higher than *amliso* and *malbans*. ADIN in *malbans* was the lowest, but was only significantly lower than *rato siris*.

There was significant interaction between the farm site and the tree species (p=0.005) in the concentration of insoluble but available protein (IAP). All other variables were not affected by site or season and also there was no interaction between the tree species and season. The available protein (TAP) (per 100g CP) ranged from about 84% in *gogun* to about 99% in *malbans*. The available protein was significantly different between tree species (p=0.036). There was also significant interaction between the site and tree species. *Malbans*, *badahar* and *amliso*, considered as *posilo* tree fodders contained more available protein than other fodders. With exception of *chuletro*, *kamposilo* tree species were generally lower in available protein (per 100g of CP).

7.3.3 Association between *posilopan* and crude protein (and its fractionates)

7.3.3.1 Crude protein, soluble protein and Total available protein and posilopan

Plot of a trend line (Figure 7.1) revealed that there was only a slight positive relationship between the farmers' rank for *posilopan* and crude protein content (R^2 0.12). A similar, weak relationship was also observed with soluble protein (R^2 0.14) and total available protein (R^2 0.16).

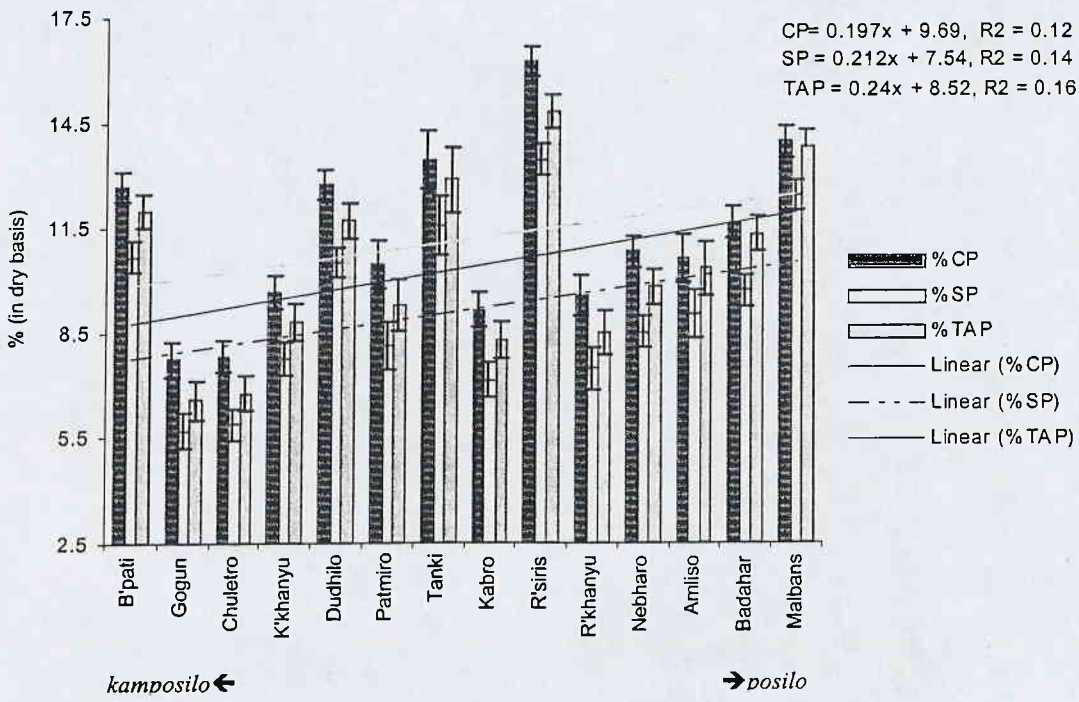


Figure 7.1 Relationship between farmers' preference for *posilopan* and CP, SP and TAP content (figure with SE bar and trend lines)

7.3.3.2 Posilopan and ADIN and IAP

Only a faint negative relationship could be seen between the concentration of acid detergent insoluble nitrogen (ADIN) and the farmers' rank order for *posilopan* (Figure 7.2). Farmers tended to rank tree species such as *malbans* and *amliso* highly, and these contained lower levels of ADIN than the lower ranked species that contained relatively higher concentrations. Despite higher content of crude protein in *rato siris*, the ADIN content was also proportionally higher in *rato siris*. However, there was a stronger relationship of farmers *posilo* ranking of tree species in terms of the content of IAP (R^2=0.42) (Figure 7.2)

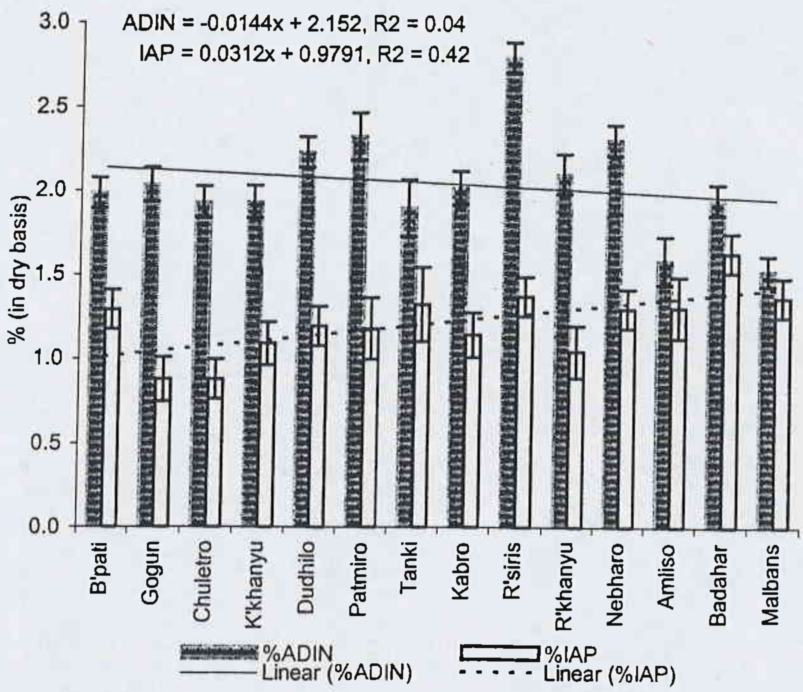


Figure 7.2 Relationship between *posilopan* and ADIN and IAP (figure with SE bar and trend line)

7.3.3.3 Posilopan and available protein

Comparison of farmers' ranking for *posilopan* revealed that there was a tendency of farmers ranking the tree species that supply higher available protein more highly for *posilopan* (Figure 7.3).

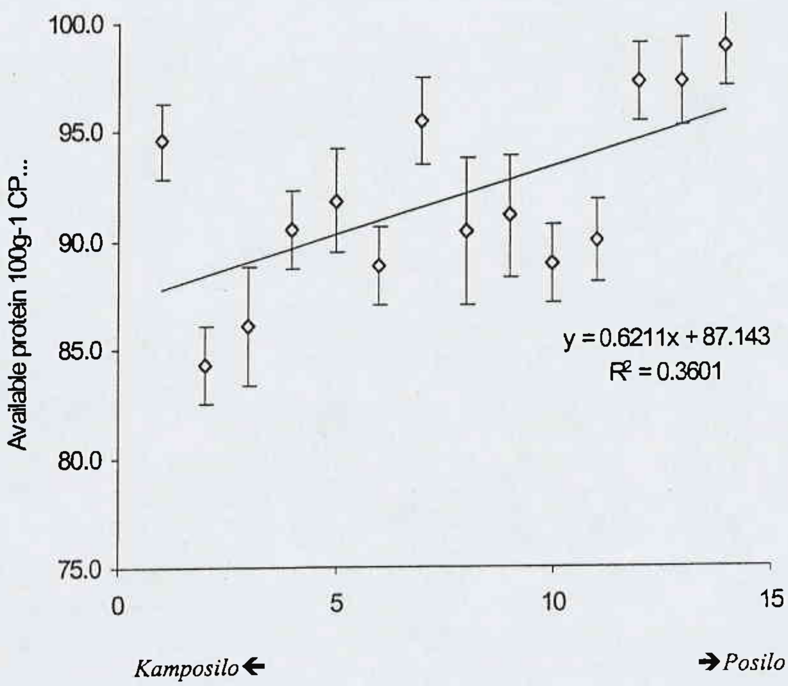


Figure 7.3 Available protein (per 100g CP) in tree leaves (trend line with SEM)

7.3.3.4 Seasonal variation in the concentration of CP, SP and TAP

Seasonality of CP, SP and TAP is shown in Figure 7.4. Season had significant effect on the concentration of crude protein (p=0.008), soluble protein (p=0.007) and total available protein (p=0.033). All other parameters studied were not affected by season. There was also significant interaction between tree species and season for parameters CP (p=0.034), SP (p=0.032) and TAP (0.038) indicating that these parameters behave differently with changes in season. Although, the concentration of CP, SP, TAP was more or less similar between 2nd (mid Jan- mid March) and 3rd season (mid March-mid

June), the values in both of these seasons were slightly higher than the 1st season (mid Nov-mid Jan). Leaves were generally mature in the 1st season, over mature in the 2nd season and immature in the 3rd season (Table 7.1)

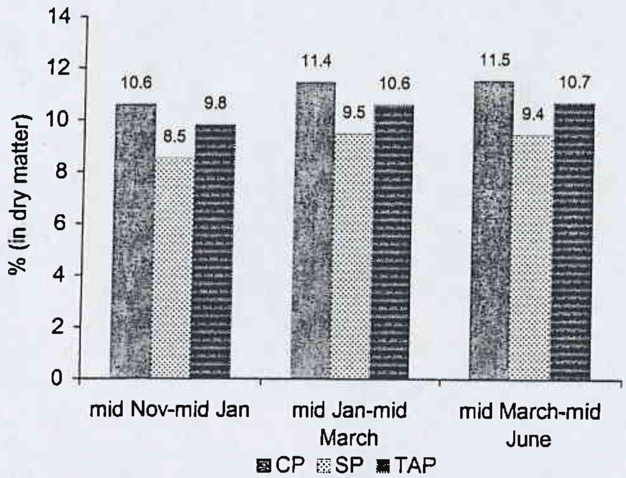


Figure 7.4 Seasonality of CP, SP and TAP in tree leaves

7.3.4 Total phenols, non-tannin phenols, tannins and condensed tannins (%, in drymatter)

7.3.4.1 Total extractable polyphenolics

The higher total extractable polyphenolics containing tree species were *khasre khanyu* (5.15%), *gogun* (4.27%), *rai khanyu* (4.22%) and *patmiro* (4.19%). *Amliso* was the tree species that contained least (2.25%) total extractable polyphenolics. *khasre khanyu* (5.15) > *gogun* (4.27)>*rai khanyu* (4.22) > *patmiro* (4.19) > *kabro* (4.01) > *dudhilo* (3.97) > *nebharo* (3.22) > *badahar* (3.18) > *chuletro* (3.07) > *malbans* (3.05) >*tanki* (3.01)> *rato siris* (2.98) >*bhimsenpati* (2.64) > *amliso* (2.25)

7.3.4.2 Total phenolics

The concentration of total phenols was significantly different between tree species (p=0.010). The concentration of total phenols (%, in dry matter) ranged from 2.41% in *amliso* to 5.98% in *khasre khanyu*. *Malbans* and *badahar* were the preferred tree species in terms of their *posilopan* contained 2.64% and 3.28% total phenolics respectively. The highest to lowest order of total phenols was *khasre khanyu* (5.95) > *rai khanyu* (4.80) > *patmiro* (4.41) >*dudhilo* (3.97)>*kabro* (3.95) >*gogun* (3.64) >*badahar* (3.28) >*chuletro* (2.98) > *nebharo* (2.91) >*rato siris* (2.87) >*tanki* (2.83) > >*bhimsenpati* (2.82) >*malbans* (2.64) >*amliso* (2.41)

7.3.4.3 Tannins (as Tannic acid equivalent)

There were significant differences amongst tree species in the concentration of tannins (p=0.001). Tannin content (%, as tannic acid equivalent in DM) was highest in *khasre khanyu*, which was significantly higher than the tannin content in *malbans*. *Amliso* had the lowest tannin content, and the content was only significantly lower than the content in *khasre khanyu*. The highest to lowest order of tannin content (%, as tannic acid equivalent in DM) was *khasre khanyu* (4.48) > *rai khanyu* (3.55) > *patmiro* (3.42) >*kabro* (2.76) >*dudhilo* (2.74) >*gogun* (2.63) >*badahar* (1.99) >*nebharo* (1.95) >*chuletro* (1.93) >*tanki* (1.60) >*rato siris* (1.50) >*bhimsenpati* (1.42) >*malbans* (1.31) >*amliso* (1.15)

7.3.4.4 Condensed tannins (Proanthocyanidin)

There was significant difference between tree species in the concentration of tannins (p=0.001) and condensed tannins (p =0.000). Condensed tannin in *gogun* was the highest and it was significantly higher than *amliso*, *badahar*, *kabro*, *bhimsenpati*, *chuletro*, *dudhilo*, *khasre khanyu*, *malbans*, *patmiro*, *rai khanyu* and *rato siris*. The condensed tannin content was lowest in *malbans* and was significantly lower than the content in *badahar*, *gogun*, *kabro*, *khasre khanyu*, *patmiro* and *rai khanyu*. The highest to lowest levels of condensed tannin (% dry matter) found was *gogun* (1.85) >*nebharo* (1.39) >*rai khanyu* (1.23) > *badahar* (1.18) > *kabro* (1.18) > *khasre khanyu* (1.17) > *patmiro* (1.04) >*dudhilo* (0.58) > *rato siris* (0.54) >*tanki* (0.45) > *bhimsenpati* (0.43) > *amliso* (0.41) > *chuletro* (0.37) > *malbans* (0.22).

7.3.4.5 Impact of season on tannins, phenols and polyphenolics

Farm site did not have significant effect on the levels of total phenols, total extractable polyphenolics, tannins and condensed tannins. Except for condensed tannins (p=0.000) and total extractable polyphenolics (0.010), all other parameters were not significantly affected by season. Although, there was a significant interaction between tree species and season (p=0.000), there was no interaction between tree species and total extractable polyphenolics.

Concentration of condensed tannins in tree leaves was generally found to be higher during mid March –mid June, and declined over this time period. A clear pattern of decrease in concentration of condensed tannins with advancing season can be seen in *badahar, amliso, rato siris, patmiro, dudhilo* and *khasre khanyu* (Figure 7.5).

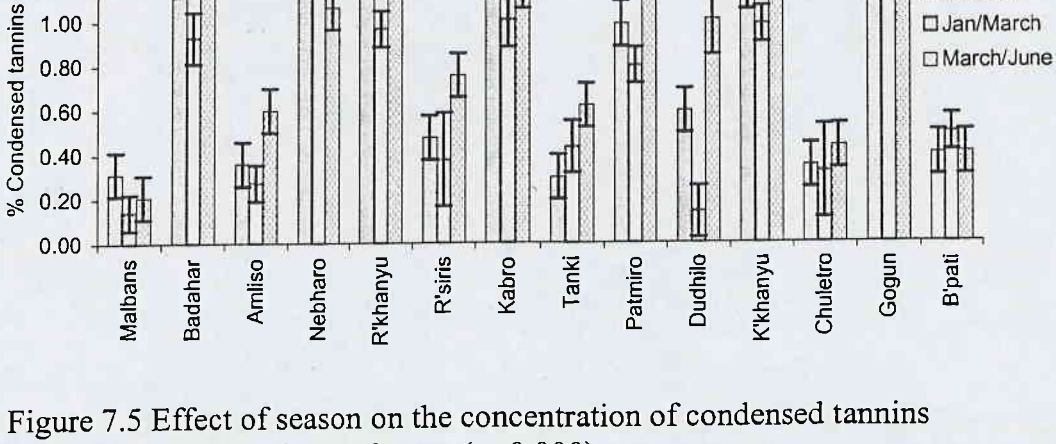


Figure 7.5 Effect of season on the concentration of condensed tannins (proanthocyanidins) in tree leaves (p=0.000)

In contrast, the concentration in *nebharo* was found to increasse over time. The concentration of condensed tannins in *rato siris, tanki* and *chuletro* was found to be generally higher in mid March-mid June than either in mid Nov-Mid Jan or mid Jan-mid March. But, there was no specific trend of concentration of condensed tannins in *malbans* and *bhimsenpati.*

7.3.4.6 Seasonality of condensed tannin and total extractable polyphenolics

Analysis of pooled data showed that the concentration of total extractable polyphenolics and condensed tannins were affected by season or leaf maturity. The concentration of total extractable polyphenolics (Figure 7.6) was found to increase with leaf maturity being low when the leaves were young (mid March-mid June) but increased with increase in leaf maturity, being highest in over mature tree leaves. In contrast, concentration of condensed tannin was highest in immature leaves but this decreased with increase in leaf maturity (Figure 7.6).

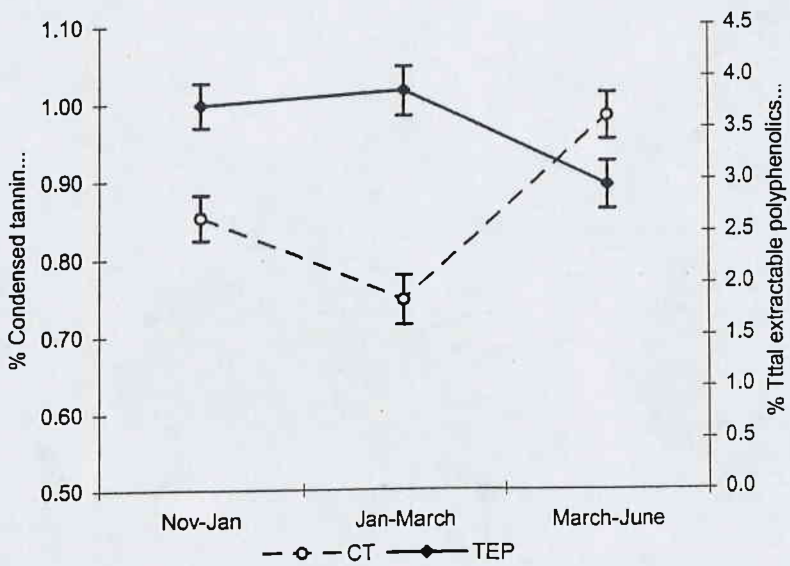


Figure 7.6 Effect of season on total extractable phenolics (TEP) and condensed tannin (CT)

The effect of season on the concentration of the total extractable polyphenolics and condensed tannins was significant ($p<0.01$) and highly significant ($p<0.001$) respectively.

7.3.4.7 Potential cumulative gas productivity

Least squares means of potential gas production with or without PVPP treatment with standard errors of means are presented in Table 7.3. Average results of duplicate determinations with or without PEG treatment conducted at Macaulay Land use Research Institute (MLURI), Aberdeen, Scotland are also presented for comparison[17] (Appendix 7.1).

Table 7.3 Average Potential gas production (SEM) with or without PVPP treatment.

Tree spp[1]	PVPP treated	Untreated
Malbans	40.3 (0.80)	40.7 (0.80)
Badahar	64.7 (0.87)	64.3 (0.87)
Amliso	41.5 (0.80)	37.1 (0.80)
Nebharo	46.6 (0.87)	44.3 (0.87)
Rai khanyu	42.8 (0.80)	35.8 (0.80)
Rato siris	51.8 (1.21)	42.1 (1.21)
Kabro	57.0 (1.78)	56.2 (1.78)
Tanki	46.2 (0.87)	39.7 (0.87)
Patmiro	49.1 (0.80)	40.4 (0.80)
Dudhilo	64.8 (1.11)	58.7 (1.11)
Khasre khanyu	53.5 (0.87)	51.0 (0.87)
Chuletro	60.5 (1.21)	57.8 (1.21)
Gogun	55.6 (0.80)	43.7 (0.80)
Bhimsenpati	44.2 (0.80)	43.2 (0.80)

[1] Tree species are in ascending rank order from most *posilo* (*malbans*) to most *kamposilo* (*bhimsenpati*)

The first two trees species, *malbans* and *badahar* ranked, as the most *posilo* tree species were not affected by PVPP treatment. Data analysis revealed a significant difference

[17] The results of the gas production analysis carried out in Nepal were more or less similar to that of the results reported by MLURI. Slight differences could be because of the differences in collection time of the tree leaves. The gas production result of MLURI (UK) was based on PEG on samples collected between January and February whilst, that of Nepal was based on PVPP on the pooled data of the samples collected between mid October and mid April.

between PVPP treated (T) and untreated (U) tree leaves on potential gas production (PD) (p=0.038). Also, there was significant interaction between the treatment and the tree species (p=0.000). The PD in *dudhilo* (T) was the highest and was only significantly higher (p=0.000) than *amliso* (TU)[18], *malbans* (TU), *nebharo* (TU), *rai khanyu* (TU) and *tanki* (TU). The PD of *rai khanyu* (U) was the lowest, and was significantly lower (p=0.000) than that of *badahar* (TU), *chuletro* (TU), *dudhilo* (TU), *gogun* (T), *kabro* (TU) and *rato siris* (T).

7.3.4.8 Results of analysis of variance for cumulative gas production constants and potential

Analysis of variance of gas production data using GLM showed that factor 'b' and 'PD' only were significantly different between treatments (with PVPP and without PVPP) ($p<0.05$). However, all the variables ('a', 'b' and 'c' and 'PD') were significantly different between tree species (p=0.000) and there was significant interaction between treatment and tree species (p=0.000) on these variables. There was also significant interaction between the site and tree species on variables 'b' (p=0.003) and 'PD' (p=0.009).

7.3.4.9 Impact of treatment of PVPP on changes in potential gas production

Analysis of net change in potential gas production (Table 7.4) showed no affect of site or season, and there was no interaction between tree species with season or site. The net change in gas volume is the difference between PD of PVPP treated and PVPP untreated samples. The PD was however found to be significantly different between tree species (p=0.000).

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[18] TU is both PVPP treated (T) or untreated (U) leaf samples

Table 7.4 Analysis of variance for mean differences in gas production between PVPP treated and untreated samples.

Source of variation					
Variable	Site	Tree spp.	Site*season	Season	Tree spp. *Season
Mean difference [a]	0.090	0.000	0.505	0.809	0.354

[a] difference between the potential gas production of PVPP treated and PVPP untreated leaf samples

Impact of treatment of PVPP on potential gas production (PD) can be better understood by observing the net changes in gas production. The net change in gas volume is presented in Figure 7.7 Farmers' ranking for *posilopan* is presented below the horizontal axis of the figure for comparison.

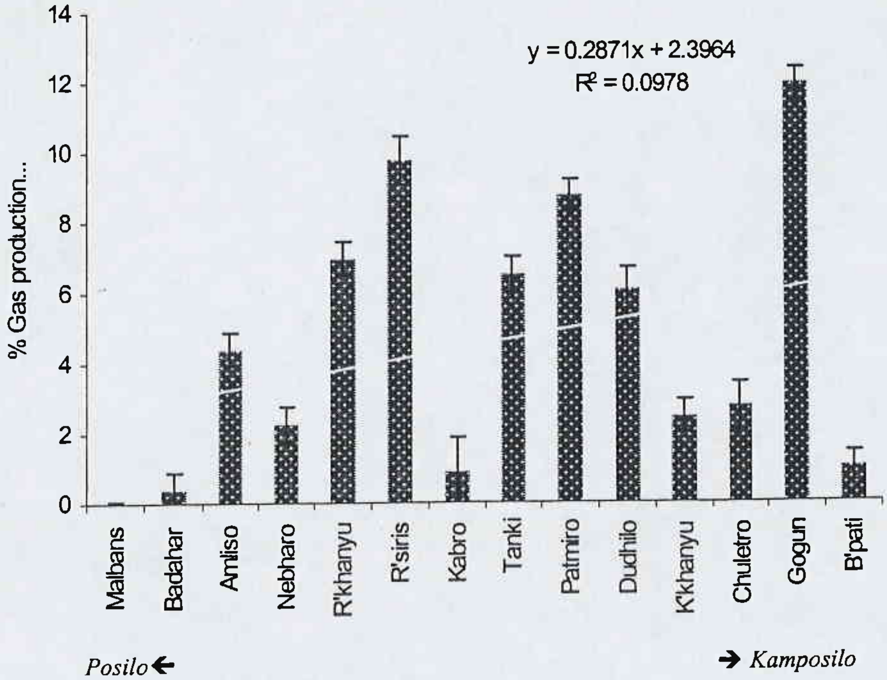

Figure 7.7 Changes in the gas volume in the leaves of different tree leaves (figure with standard error bar)

Farmers' ranking for *posilopan* appeared to be roughly related to the fermentability of tree leaves (Figure 7.7). There was a tendency that the tree species with no changes or little changes in gas volume were generally regarded as *posilo* types of fodder and those with more gas volume as *kamposilo* types of fodder. In other words, the tree leaves with substances that cause inhibitory effects on gas production produced more changes in cumulative gas production than the tree leaves that contained less. However, only a weak positive relationship was observed between the net change in gas production and concentration of tannins or phenolics in tree leaves. Individual regression analysis between the 'net change in gas production' (NEP) and total phenols, total extractable polyphenolics (TEP), tannins and condensed tannins were as follows:

NEP= 3.65 + 0.276 total phenols, R^2=1.3, p=0.169

NEP= 2.72 + 0.543 TEP, R^2= 4.4, p=0.01

NEP= 3.70 + 0.403 tannins, R^2 =2.2, p=0.068

NEP= 2.58 + 2.36 condensed tannin, R^2=9.6, p=0.00

Only a slightly stronger relationship was obtained with condensed tannins. This indicated that among other phenolics, condensed tannin (Proanthocyanidin) was more responsible in influencing gas production.

7.3.4.10 Effect of season on cumulative potential gas production

Analysis of variance of cumulative gas production data using GLM showed that the PD was significantly different between seasons (p=0.048) and there was also significant interaction between tree species and season on variables 'b' (p=0.001), 'c' (p=0.035) and 'PD' (p=0.000).

Figure 7.8 shows the potential gas production (linear plot with SEM) plotted by season from pooled data from treated and untreated samples. Analysis of variance for PD was found to decrease with season (p=0.048). As anticipated the over mature leaves of mid January to mid March contained relatively lower cell contents than either mature or immature tree leaves[19], this was revealed in cumulative potential gas production of the leaf samples (Figure 7.8).

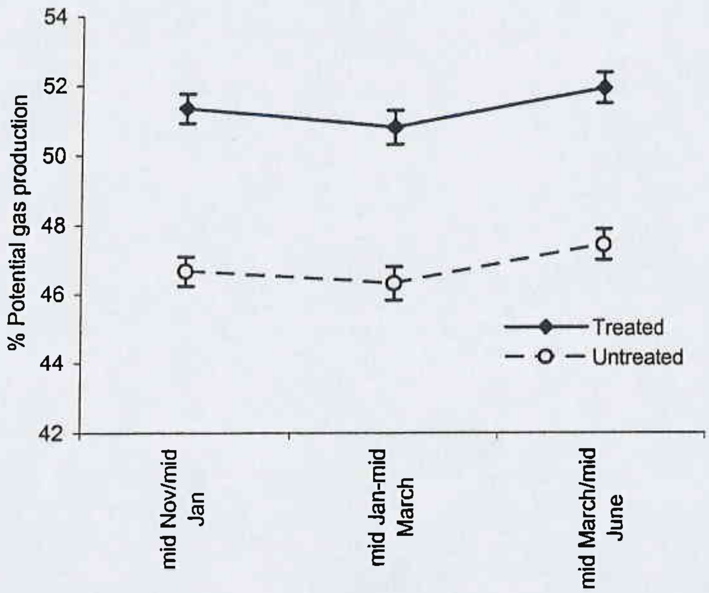

Figure 7.8 Potential gas production as affected by season and PVPP treatment (figure with SEM)

The total gas inhibition (difference of gas production between treated and untreated samples i.e. 4.5%) was, however, more or less the same for all seasons.

Surprisingly, the potential gas production was found to be inversely related to total extractable polyphenolics and closely positively related to the concentration of condensed tannin (Figure 7.6). Otherwise, it was believed that all tannins have gas-inhibiting properties.

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19 Stages of maturity of leaves: please see also Table 7.1.
Immature leaves – mid March – mid June
Mature leaves - mid Nov-mid Jan
Over mature leaves – mid Jan – mid March

7.3.4.11 Interaction between tree species and season on volume of gas production

There was a significant interaction between tree species and season (p=0.000). The potential gas production of *badahar* leaves was the highest during mid Nov-mid Jan and was significantly higher than the PD of *amliso* (mid Nov-mid Jan, mid Jan-mid March), *malbans* (mid Jan-mid March) and *khasre khanyu* (mid Jan-mid March, mid March-mid June). The PD of *amliso* was the lowest during mid Nov-mid January but was only significantly lower than the PD of *badahar* during this period. Interaction between tree species and season on the gas production of tree leaves is presented in Appendix 7.2.

7.3.4.12 Interaction between site and tree species on potential gas production (F=Fakchamara, P=Patle)

There was a significant (p=0.009) interaction between sites and tree species. Potential gas production of *badahar* leaves of Fakchamara (F) was the highest and was significantly higher than *amliso* (FP)[20], *bhimsenpati* (FP), *gogun* (FP), *khasre khanyu* (FP), *malbans* (FP), *nebharo* (FP), *patmiro* (FP), *rai khanyu* (FP), *rato siris* (FP) and *tanki* (FP). The PD of *amliso* (P) was the lowest, but only significantly lower than *badahar* (FP), *chuletro* (FP), *dudhilo* (FP) and kabro (P) and *khasre khanyu* (P). Interaction between site and tree species on the potential gas production in tree leaves collected from Fakchamara and Patle is shown in Appendix 7.3.

[20] FP is the fodders trees of both sites i.e. Fakchamara and Patle

7.3.4.13 Association between adilopan and 'a', 'b' and 'c' fractions of gas production

Analysis of variance of the untreated samples revealed that there was significant difference between the tree species on a, b and c values ($p<0.001$). Relationships between farmers ranking for *adilopan* (Section 3.4.2.1) and the fractions 'a' or 'b' or 'c' and 'PD' are shown in Figures 7.9a, 7.9b, 7.10a and 7.10b respectively *(in the figure, farmers' ranking for adilopan is given along X' axis; low to high scale is from left (dudhilo most kamadilo to amliso most adilo).*

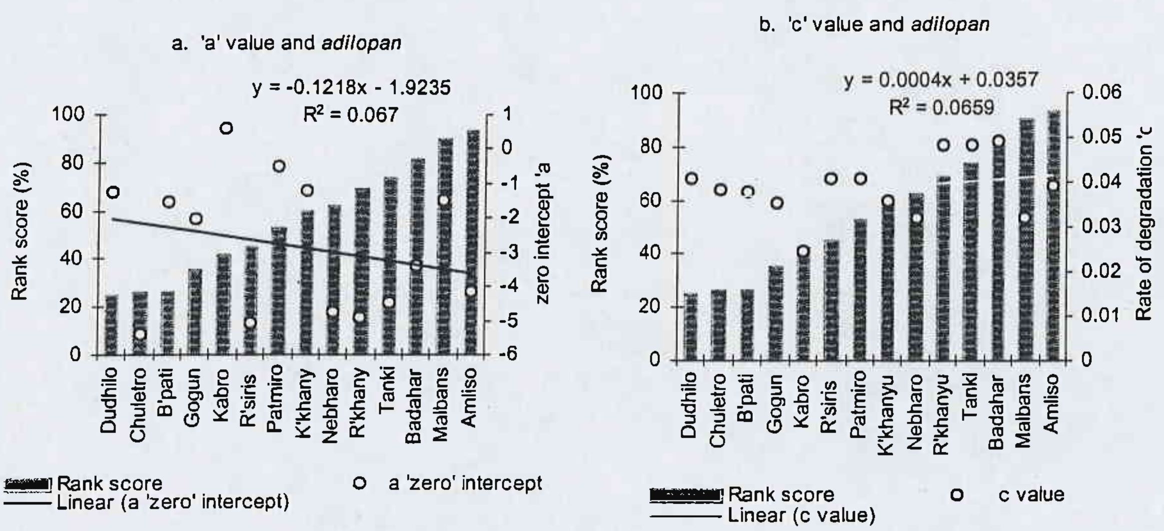


Figure 7.9 Farmers' ranking on *adilopan* and gas production fraction 'a' (a) and the rate of degradation 'c' (b)

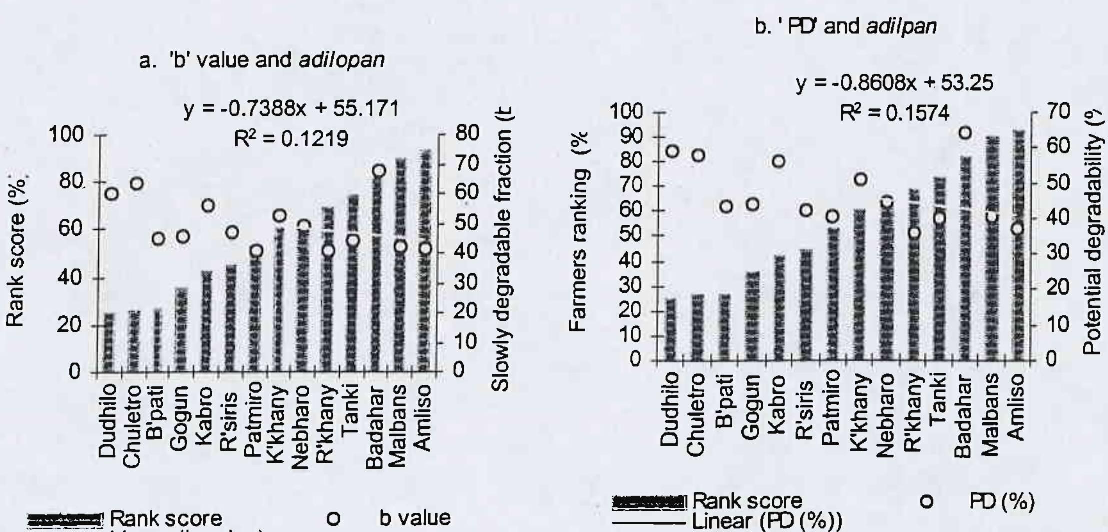


Figure 7.10 Farmers' ranking on *adilopan* and slowly degradable fraction 'b' (a) and the rate of potential degradability 'PD' (b)

Except *kabro*, all other species of leaves showed negative 'a' value. This has shown that the microflora responsible for degrading organic matter in tree leaves required longer time to colonise and degrade cell wall and cell contents. A simple regression analysis showed that there was no apparent relationship between the farmers' ranking for *adilopan* and 'a' value (Figure 7.9a) and 'c' value (Figure 7.9b).

However, there is a slight negative association between farmers' ranking for *adilpan* and slowly degradable fraction 'b' and the potential degradability could be seen. However, except for *badahar*, a pattern that the higher the 'b' or 'PD' values the lower the farmers' rank score can be seen in Figures 7.10a (b value) and 7.10b (PD).

7.4 Discussion

Association of protein (and its fractionates) with farmers preference for *posilopan*

There was an indication of existence of a relationship between farmers' knowledge of *posilopan* with chemical parameters. Among all the chemical parameters, IAP and available protein (per 100g CP) gave somewhat better-related linear trends. The regression coefficients R^2 were 42% and 36% respectively. According to Van soest and Robertson (1985), indigestible and available protein (IAP) is the protein type that is slowly degraded in the rumen but is digested in the intestines. Therefore, it is anticipated that the local people are more in favour of a protein that escapes rumen fermentation than a high level of crude protein, rumen soluble protein (SP) or total available protein (that combines rumen soluble and insoluble protein). This understanding could be related with the nutrient intake (recorded through repeated measurements) by local animals (Chapter 2) that the local animals received low level of protein and low energy diets. In absence of energy, protein in the diet could be excreted through urine and wasted. This protein and energy imbalance in the diet of local animals, may have been considered by farmers to choose a protein type that escapes rumen fermentation but becomes available for body use in the lower gut of animals such as IAP. This assumption agrees with the earlier findings by Thorne *et al.* (1999). They reported that *posilopan* appeared to correspond to protein supply to the duodenum in ruminant animals.

Generally farmers' knowledge for *posilopan* was based on their implications on the productivity of animals. However, it is possible that while ranking for preferences, the farmers may also have considered other perceived facts that could have influenced their ranking.

Posilopan also varies with the type or species of animals they are fed to (Thapa, 1994), since the tree species that is *posilo* to one animal species may not be *posilo* to other animal species and vice versa. The preference of trees by goat or sheep is different from that of cattle or buffalo (Section 5.3.1). The tree species, which appeared to be palatable to large ruminants were not palatable to small ruminants.

Although, *bhimsenpati* leaves have been shown to contain higher or almost similar level of protein content to other species, it was regarded as the most-*kamposilo* tree species of the 14 trees studied. The lower preference of this species by farmers could be related to its palatability to the animals. *Bhimsenpati* leaves are odorous and are not generally palatable to animals, large ruminants in particular. *Bhimsenpati* is goat (and sheep) fodder, and so while ranking for *posilopan*, scores for small and large ruminant animals should have been distinguished. Joshi (1997) has also listed this species as unpalatable. Not many farmers knew about *bhimsenpati* in Ilam district where he conducted his study and did not have practical experience of feeding it to their animals. It is likely that the ranking by farmers in Fikkal for *bhimsenpati* was based not on experience but on a guess.

Similarly, reasons for lower preference of *tanki* and *dudhilo* in relation to the higher ranking species but having similar or lower protein content could be related to their association with negative or no changes in the productivity of animals and their health. Despite high value of its nutritive value, the lower preference of farmers for *posilopan* could be related with the farmers' ranking disregarding the sub-species differences. Broadly there are two sub-species *sanopate* and *thulopate-dudhilo*. The latter is regarded as more *posilo* than the former. Also, farmers consider *sanopate-dudhilo* to be more *chiso* than *thulopate-dudhilo*. *Sanopate-dudhilo* is preferentially given to goats and sheep (Thapa, 1994) whilst, *thulopate-dudhilo* is fed to all animal types.

Farmers could have also considered the deleterious effect to the animals when leaves are fed when they are at flushing stages. They may also have taken into account the practical difficulties of wilting young leaves prior to feeding. The farmers might also have ranked *dudhilo* irrespective of sub-species variants that some of them know exist.

Even though *tanki* was found to be one of the major species that contain higher levels of protein or protein fractionates, it was ranked as an average type of fodder in terms of *posilopan*. It is likely that the farmers might have reduced the rank they gave to *tanki* because of its susceptibility to pests and diseases (Section 3.5.2).

Similar was the ranking position of *rato siris* despite its highest content of protein and other protein fractions. This could be related with the actual feeding practices since not many farmers utilize *rato siris* as a fodder to feed their animals. Farmers might also have considered for its green manure value since *rato siris* leaves have been known as a potential source of green manure (Subedi, 2000). Another reason could be related with the biomass it can give. A mature *rato siris* tree, on average, yields about 1 *bhari* per year (equivalent to about 35 kg), which is just enough to feed 4 to 5 large animals (Section 2.4.1.1). Since the leaves drop and become unfit to collect or feed to the animals if the feeding is delayed beyond a day or so, they require immediate feeding after the collection. On the other hand, the consequences of immediate feeding have been reported to be fatal to the animals particularly at the time of fodder shortage. *Rato siris* is known to cause toxic effect to the animals when it is fed at the time of fodder shortage. There are reported cases of poisoning and even death when the animals are fed accidentally (or by children) during mid-March/mid-April when the leaves are at flushing stage. Therefore, it likely that these might have influenced farmers in their evaluation of tree fodders. As a result farmers' might have made their ranking irrespective of the content of proteins or fractionates in them. Therefore, it was worth trying to examine the relationships between the farmers' ranking for *posilopan* excluding the tree species described above (*bhimsenpati*, *dudhilo*, *tanki* and *rato siris*) from the analysis.

Relationship between *posilopan* and crude protein (CP), soluble protein (SP), total available protein (TAP) and overall protein supply (AP)

Exclusion of *rato siris, tanki*, *bhimsenpati* and *dudhilo* from the analysis revealed a strong relationship between farmers' ranking for *posilopan* and the crude protein parameters (Figure 7.11).

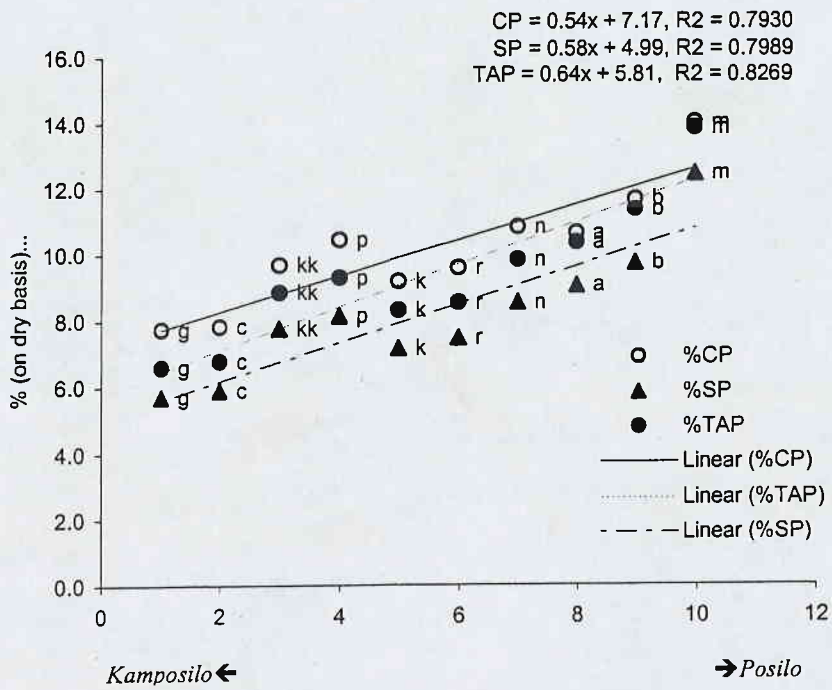


Figure 7.11 Relationships between *posilopan* and CP, SP and TAP. Keys in the graph are g=*gogun*, c=*chuletro*, kk=*khasre khanyu*, p=*patmiro*, k=*kabro*, r= *rai khanyu*, n=*nebharo*, a=*amliso*, b=*badahar*, m=*malbans*

Although, the strength of the relationship between *posilopan* and the CP or SP or TAP was more or less similar, there was a slightly strong relationship between *posilopan* and TAP (R^2=0.8269). However, the farmers' preference for *posilopan* was found to be even more strongly related with the overall available protein (AP per 100g CP) ($R^2 = 0.8317$) (Figure 7.12).

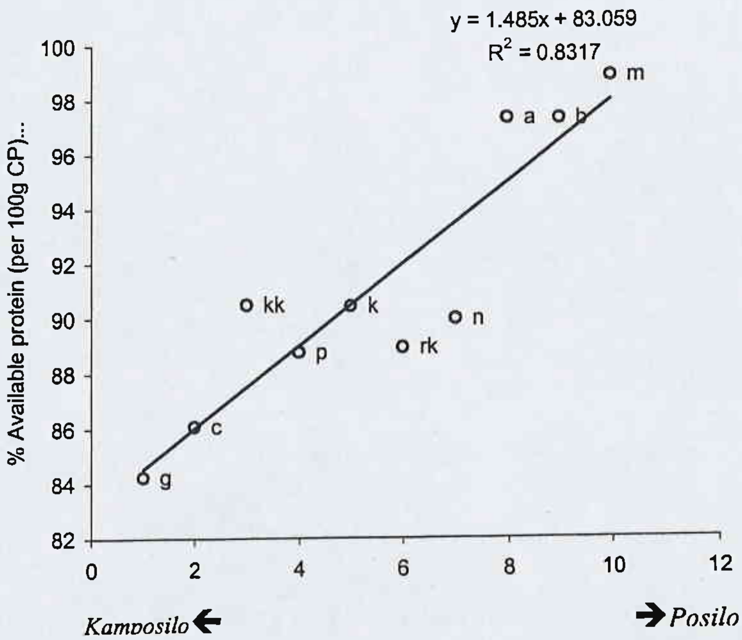


Figure 7.12 Relationship between available protein (AP g $100g^{-1}$ CP). Keys in figure are g=*gogun*, c=*chuletro*, p=*painyu*, kk=*khasre khanyu*, rk=*rai khanyu*, k=*kabro*, n=*nebharo*, a=*amliso*, b=*badahar* and m = *malbans*

Posilopan and insoluble but available protein (IAP) and acid detergent insoluble nitrogen (ADIN)

Despite higher concentrations of CP, SP and TAP (Table 7.2), proportionally the concentration of ADIN in *rato siris* was also high (Figure 7.13). It can be attributed that the higher concentration of ADIN could be one of the reasons why farmers placed *rato siris* as an average quality fodder in terms of *posilopan*. The significantly low content (p=0.001) of ADIN in *malbans* also reflected why *malbans* was popular among farmers as the most *posilo* fodder.

The acid detergent insoluble nitrogen (ADIN) is a protein type that is regarded as an indigestible (poorly digestible) and unavailable protein (poorly available) fraction for animals for body utilisation (Undersander, 1993; Van soest, 1994.).

Ranking by farmers for *posilopan* was inversely related to the content of ADIN in tree leaves. Elimination of *rato siris*, *tanki*, *bhimsenpati* and *dudhilo* from the analyses also did not improve the relationships much between ADIN and farmers' ranking for *posilopan* (the change was from R^2 =0.04 to R^2 =19 only, Figure 7.13).

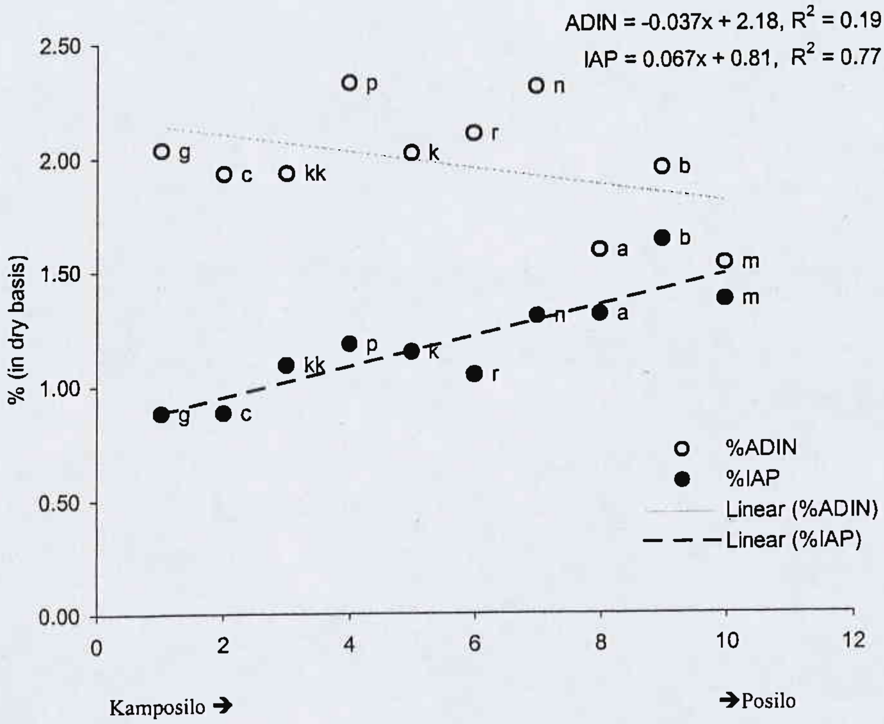


Figure 7.13 Relationships between *posilopan* and ADIN and IAP. Keys in figure are g=*gogun*, c=*chuletro*, p=*painyu*, kk=*khasre khanyu*, rk=*rai khanyu*, k=*kabro*, n=*nebharo*, a=*amliso*, b=*badahar* and m = *malbans*

The weak relationship (R^2 = 0.19) could possibly be due to farmers considering some other facts that become essential to a farming component, for example, manure quality. Majority of farmers (Section 3.6.2) preferred manure quality that should sustain not only the current crop but should also carry on its manuring effect to subsequent crops (locally termed as '*tikau*'). In other words, additional manure is not required if *tikau* manure was applied in the previous crops. Since, ADIN is a protein fraction that is excreted undigested (or little digested) in the animal system, perhaps due to bonding in a matrix between lignin and tannin (Van Soest, 1983), anticipating that such protein fractions are gradually released and become available for long-term fertility and sustainability of farmland.

There was improvement in the relationship between IAP and farmers' ranking for *posilopan,* R^2 from 0.42 (Figure 7.2) to 0.77 (Figure 7.13). However, the strength of this relationship was weaker than the overall available protein ($R^2 = 0.8317$) (Figure 7.12).

Posilopan and seasonality of protein and its fractionates

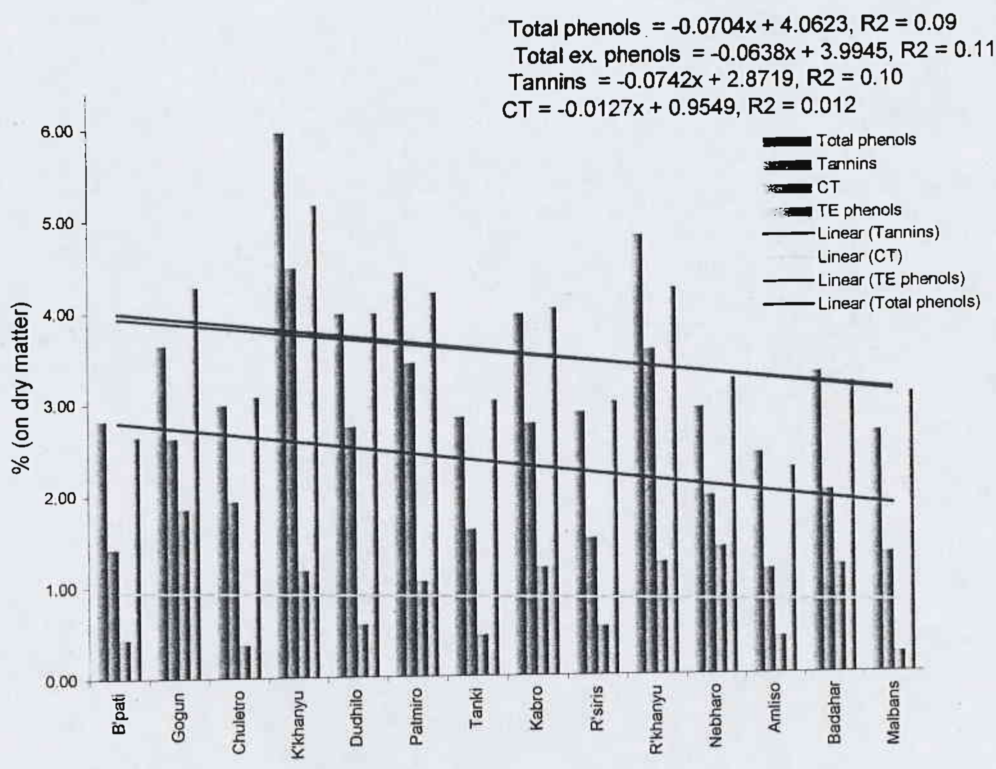
Majority of farmers in the eastern hills reported that tree species become less nutritious and unpalatable as the leaves mature. They reported that mature leaves are more palatable than the leaves, which are immature or over mature.

Similar, was the experience of farmers in Solma VDC in Terhathum district. Thapa (1994) also reported that the farmers considered that both immature and over mature leaves are bitter in taste and consequently drop in palatability of tree fodder. Hence, the farmers considered intermediate leaves (mature leaves) as more *posilo* than either immature leaves or over mature leaves (senescing).

The parameters that were significantly affected by season were crude protein, soluble protein and total available protein (Figure 7.4). Farmers' interpretations that immature leaves (mid March/mid June) or over mature leaves (mid Jan – mid March) are more *kamposilo* than mature leaves (mid Nov/mid Jan) is inconsistent with measured levels of proteins. However, the leaves during mid Jan/mid March were pooled and were the mixture of both young (immature) and over mature leaves (Table 7.1) shows that the leaves between Feb and March were both young and over mature leaves). Hence, the result did not truly depict the picture of over mature leaves. However, it could also be possible that the farmers considered the deleterious and anti-nutrient effects of young leaves or over mature leaves more than the nutrients they supplied.

Effect of PVPP on effects on cumulative gas production

The first two trees species, *malbans* and *badahar* ranked, as the most *posilo* were not affected by PVPP treatment whilst, the *kamposilo* tree species were relatively more affected by PVPP treatment (Figure 7.7). This indicated that the presence of natural toxicants or anti-nutrients could be the agent responsible to effect fermentation of nutrients and thus, gas production. Farmers' practical experiences on the use of trees over time could have led them to understand and distinguish *posilo* or *kamposilo* quality based on



these factors.

Figure 7.14 Tannins and phenolics (%) in tree fodders. Significant amongst tree species total phenols ($p=0.010$), tannins (as tannic acid equivalent, $p=0.001$), condensed tannins ($p=0.000$) and TE polyphenolics ($p=0.034$).

Result of the tannins and phenolics (Figure 7.14) supported this finding that *kamposilo* tree leaves contain relatively more tannins and phenolics than their concentration in *posilo* type of tree species. The weak but positive association of net gas production and tannins or phenolics (i.e. lower net gas production in *posilo* and higher net gas production in *kamposilo* fodder) also supports this.

Response to PVPP treatment (Figure 7.7) was high in the samples with increase in net gas production or increase in concentration of phenolic compounds in tree species. This shows that the nutrient availability of tree leaves can be improved by treatment of the tree leaves containing higher levels of tannins with materials such as PVPP.

Although the tannins (tannic acid) and total phenolics or total extractable polyphenolics in *khasre khanyu* was the highest, this was not reflected in gas production assays when the leaves were treated with PVPP. This is perhaps PVPP has less affinity to combine with the type of phenolics that is present in *khasre khanyu* or it is also possible that the unit of PVPP used to treat the leaves was not enough to bind the phenolic molecules present in *khasre khanyu*. According to Makkar and Goodchild (1996) 200mg of PVPP is required to bind about 4 mg of total phenols.

Seasonality on the concentration of tannins and phenolics

Concentration of condensed tannin was found to decrease with an increase in leaf maturity and this is in contrast with general understanding of a relationship often reported in browse plants. Most workers reported that the concentration of condensed tannins in browse species increase with increasing leaf maturity. The total extractable phenolics was also significantly increasing ($p=0.01$) with the maturity of leaves. This is also in contrast with Dawra *et al.* (1988) and Makkar *et al.* (1988) who suggested that hydrolysable tannins (total phenolics) decrease as the leaves mature. However, a positive relationship between the levels of lignin and tannin (gallo-tannic acid equivalent) reported by Subba *et al.* (1996) ($R^2=0.72$ at $p<.01$) and Kaitho *et al.* (1998) ($r=0.86$, p<0.001) agreed with the current finding suggesting that tannin concentration increases with advancing age of the leaves.

Tolera *et al.* (1997), in his report, concluded that concentration of phenolic compounds particularly condensed tannins are the main factors depressing the *in-sacco* degradability and *in-vitro* gas production potential of browse plants. However, his study was limited to very few browse species. Inverse relationships of the potential gas production with total extractable polyphenolics and positive association with the concentration of condensed tannin suggested that total extractable polyphenolics are responsible to inhibit gas production. They are therefore important in animal nutrition research.

Relationship between tannins/phenolics and *posilopan*

Figure 7.7 also showed that the farmers' tended to prefer *posilo* type of tree species that are relatively lower in the net gas production when the leaves were treated with PVPP. The weak but positive correlations between 'net gas production' and tannins or phenolics (R^2 =9.6) suggested that there could be other factors associated with the farmers' preference. Tree leaves with substances that inhibit gas production produced more changes in cumulative gas production than the tree leaves that contained less.

Maximum tannin (total phenols) obtained in tree fodder in this study was about 6% in *khasre khanyu* and the condensed tannin (Proanthocyanidin) content was about 2% in *gogun*. On animal nutrition perspectives, lower concentrations of condensed tannins are beneficial while higher concentrations were reported to be detrimental to the health and productivity of animals.

Tree species that contain moderate levels of tannins could possibly provide adequate levels of both rumen degradable protein and non-degradable rumen protein for ruminants and in turn the farmers could possibly receive the type of manure quality they prefer (Section 3.6.2). However, identification of a moderate level of tannins in tree fodder that covers all these qualities is complex and is beyond the scope of this study.

Gurung *et al.* (1993) reported that condensed tannin (%, Catechin equivalent) is found from 0.01 in *painyu* (*Prunus cerasoides*) to a maximum of 4.75 in *koiralo* (*Bauhinia variegata*). The low rank of *koiralo* (not included in this study) as a *posilo* fodder by local farmers could therefore be attributed to the presence of high level of condensed tannin. However, the low rank (most *kamposilo*) of *painyu* among farmers did not agree with the low tannin level in it. It is likely that substances other than tannin and other animal factors might have influenced farmers' preference for *painyu*. Kumar, (1992) reported the presence of Saponin, a glycoside in *painyu*. Few factors reported by farmers are *Lahumute* (red coloration of urine), poisoning and death in some cases[21]. No apparent relationship was noticeable when comparison was made between the most *posilo* and most *kamposilo* tree species based on their contents of tannins or phenolics (Table 7.5).

Table 7.5. Tannin and phenolics (mean) in the first two most *posilo* (1st & 2nd) and the last two most *kamposilo* (14th and 15th) tree species for comparison

Tree species	Total phenols	Tannins	Condensed tannins	TEP
Malbans (1st)	2.64	1.31	0.22	3.05
Badahar (2nd)	3.28	1.99	1.18	3.18
Painyu (15th)*	3.49	2.03	0.85	3.61
Bhimsenpati (14th)	2.82	1.42	0.43	2.64

* result is the average of the samples of the months mid March – mid May only.

However, farmers' selection for *posilopan* or *obhanopan* in terms of tannins or phenolics could be related to their association with health and productivity of farm animals. Recent knowledge suggests that tannins are effective to control the effect of intestinal nematodes in ruminant animals (Kaitho *et al.*, 1998; Kabasa *et al.*, 2000). Report from a recent feeding trial conducted in buffalo calves (artificially infected with liver fluke eggs) with different nutrient sources with or without supplementation of tree fodders indicated that plant phenols could be responsible factors to improve the live weight gain in calves (Subba *et al.*, 2000). The calves in tree fodder supplemented group received commonly available tree leaves @

[21] Excessive intake of *painyu* (*Prunus cerasoides*) caused death of one (of total 4) experimental sheep of the author at ARS-Pakhribas, Dhankuta. Diagnostic investigation confirmed that the death was due to Cyanogenic glycoside poisoning.

3% live wt basis per day and the tree leaves ranged from 2 to 6% total extractible polyphenolics.

The presence of relatively higher level of condensed tannin in highly preferred fodder species (in terms of *posilopan*) such as *badahar* and *nebharo* indicated that tannin could play a role to increase the supply of nitrogen into the duodenum causing a beneficial effect on nitrogen metabolism (Hagerman *et al.,* 1998; Harborne, 1998, Maasdorp *et al.*, 1999 and Müeller-Harvey and McAllan, 1992). Since tannin can have both beneficial and negative effects, farmers may have considered the positive effects of tannins on nitrogen utilization while selecting tree fodders. The relatively higher level of IAP (by pass protein *in vitro*, Table 7.3) in these tree species suggested its positive relationships with the concentration of condensed tannin. This agrees with the findings of Reed (1986) who reported that condensed tannin was positively correlated with fibre-bound protein.

Animals in Nepal are maintained on straw based diets, as a result the majority of ruminants are infected with liver fluke. Through experience, local farmers might have considered the use of tannin containing tree species so as to reduce negative effects of gastrointestinal helminth burdens. A moderate level of tannin in the diet of ruminants has been reported to play a significant role in reducing negative effects of gastrointestinal helminth burdens (Kabasa *et al.,* 2000) and improving nutrition of ruminant animals (Subba *et al.,* 2000). Access of ruminants to optimal quantities of tannin containing fodder trees could not only minimise nutritional stress in ruminants but also reduce their dependence on anthelmintic drenches to improve productivity. So, it appears that the farmers might have considered these factors while selecting and ranking tree leaves to feed to their animals.

In the diet high in tannin, not all proteins that are bound with tannin are freed in the lower gut but are voided as such in faeces. Although, this appears to be inefficient in terms of protein utilisation, the bound protein in the manure will undergo slow degradation when incorporated in soil and could bear an important value from a whole farm system perspective. The'*tikaupan*' (Section 3.6.2), local attribute to evaluate manure quality is possibly associated with tannin that complexes with protein. Mafongoya, *et al.* (1998) reported that leaves containing high levels of polyphenolics would decompose slowly thereby slowly releasing nitrogen from the compost. Hence, tannin bound protein might have been considered by farmers for its importance of recovering manure quality that is more *tikau*, and thus considered while evaluating tree fodders.

As the ruminant species require both rumen degradable protein and rumen by-pass protein, leaves with intermediate maturity would possibly be better for animals at optimum level of productivity. It is practically impossible to select young or old leaves for feeding separately to the animals. The current feeding practices of farmers result in diets that contain both young and old leaves and appear to be logical in terms of the effective utilisation of nutrients from trees or browse species.

Relationship between gas production constants and *adilopan*

No apparent relationships were observed between *adilopan* and gas production constants 'a' showed that farmers' ranking for *adilopan* was not strictly dependent on the fraction of fodder that is rapidly degraded in the rumen. It is likely that farmers' also do consider fodder that could also be digested rapidly in the rumen as this is the fodder type that limits the productivity of farm animals in the hills. However, choice of such fodder could perhaps be governed by other factors associated with animals and the objectives of individual farm families. The poor relationship between the degradation rate 'c' and *adilopan* also suggested that the rate of degradation of food does not indicate whether or not a food is *adilo*. Relationship between *adilopan* and the fraction 'b' or 'PD' was also poor, $R^2 = 0.1219$ for 'b' ; $R^2 = 0.157$ for 'PD'). Careful examination of the data revealed that *badahar* was causing the problem (higher 'b' or 'PD' value than expected for *adilopan*). Almost equal to *malbans*, *badahar* is one of the highly preferred fodder tree species in the eastern mid hills (Section 3.5.2) and in the western mid hills (Rana *et al.,* 2000). Farmers value this species as most *posilo*, promoting milk and butterfat yield, improving health of animals (Thapa, 1994). The tree species is so dersirable that the farmers ranking of *badahar* as *posilo* fodder might have influenced them to consider it as *adilo* fodder also. It is also possible that the highly nutrious quality (i.e. high PD) characteristics of *badahar* could also be able to satisfy appetite of animals, and hence the farmers ranking of *badahar* for *adilo* fodder. When *badahar* was excluded from the analysis, the relationship was found to be better correlated i.e. R^2=0.4865 for b; R^2 = 0.5328 for PD (when *badahar* was included; R^2 was 0.1219 and 0.1574 for b and PD respectively). The negative relationship between PD and *adilopan* after *badahar* was excluded from the analysis is shown in Figure 7.15 for illustration.

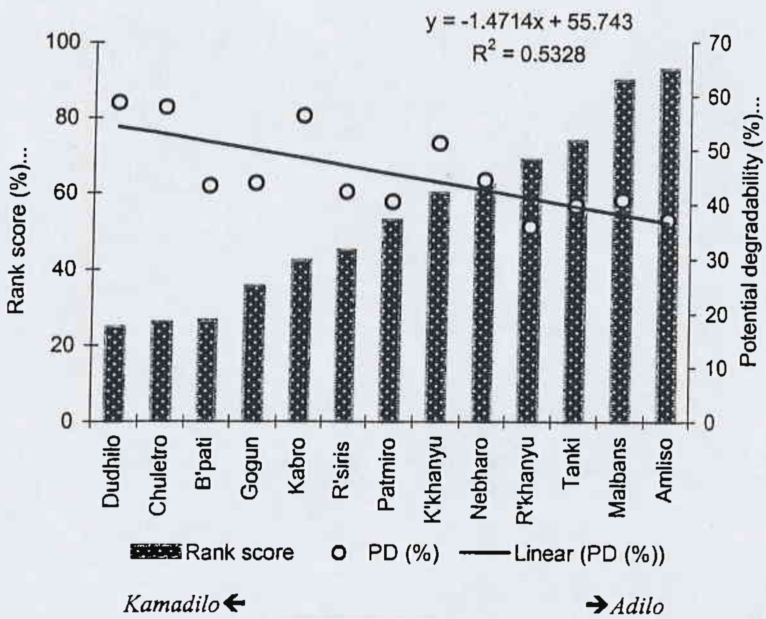


Figure 7.15 Relationship between farmers' ranking for *adilopan* and potential degradability (PD), excluding *badahar*.

The negative association between *adilopan* and potential degradability has shown that farmers consider fodder species with lower potential degradability as *adilo* fodder. This finding agrees reasonably well with the previous finding by Thorne *et al.* (1999) that *obhanopan* is associated with *in-vitro* digestibility of tree fodder. This correspondence led to the understanding that the *obhanopan* referred by Thorne *et al.*(1999) was actually the *adilo* fodder. It is now understood that *adilopan*, a different quality attribute (Section 3.4.1.1), is closely related to *obhanopan* but it is closely associated with the digestibility of food.

7.5 Conclusions

Posilopan, a key attribute to evaluate fodder quality was found to be related to protein and its solubility. Earlier report by Thorne *et al.* (1999) suggested a correspondence between protein supply to the duodenum and *posilopan*, this study indicated that CP and other protein fractions (soluble protein, total available protein) are equally important and closely related with *posilopan* of tree fodder. However, the protein that is available (per 100g of CP) has shown stronger correspondence with *posilopan* than other protein fractions. This suggested that Nepalese ruminant animals require both the protein types, soluble protein for rumen environment and rumen-escape protein for tissue synthesis. Hence, these chemical attributes appear to be recognized by farmers as *posilopan*. Generally farmers' knowledge about *posilopan* was based on their implications for the health and productivity of animals. Farmers consider not only nutritive value but also other multiple factors important to the animals or farm families. Relatively higher concentration of crude protein, soluble and available protein in young leaves was in contrast with farmers' perception that young leaves are less nutritious and unpalatable. This contrast could be because of the negative associated effects recognized by farmers in feeding young leaves particularly containing tannins. The high amount of condensed tannins but proportionally lower amount of total extractable polyphenolics in young leaves supported this assumption.

Posilo fodders such as *malbans, amliso* generally revealed lower contents of tannins than kamposilo fodders such as *khasre khanyu*. Since, *posilo* tree fodders (i.e. *malbans* and *badahar*) are generally less affected by PVPP treatment (i.e. comparatively lower net gas production in *posilo* compared to the effect on *kamposilo* tree fodders (i.e. *gogun*), this suggested that there is correspondence between farmers' understanding of *posilo* and *kamposilo* fodder with the presence of natural toxicants such as tannins.

Since tannin can have both beneficial and negative effects, farmers may have considered the positive effects of tannins on nitrogen utilization while selecting tree fodders. The presence of relatively higher level of condensed tannin in highly preferred fodder species (in terms of *posilopan*) such as *badahar* and *nebharo* indicated that *posilopan* of these tree species was based on the protein fraction that is available in duodenum.

No apparent relationships between *adilopan* and gas production constants 'a' suggested *adilopan* is not strictly dependent on the fraction of food that is rapidly degraded in the rumen. Likewise, the rate of degradation 'c' poorly compared with *adilopan*. However, there was strong negative association between *adilopan* and potential dry matter degradability, showing that farmers recognized less degradable fodders, that would be expected to have commensurately longer rumen retention times, as more *adilo* fodder. This correspondence has led to revision of the understanding of *obhanopan* articulated by Thorne et al., (1999) whose interpretation for *obhano* better fits what we now know about *adilo* fodder. It is now understood that *adilopan*, a different quality attribute (Section 3.4.1.1), close to *obhanopan*, is more precisely associated with the digestibility of fodder, while *obhanopan* is a broader term embracing dry and bulky fodders.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

Overview

This concluding chapter summarises the current findings and addresses the implications of the findings for the improvement in the nutrition of farm animals during the dry season in the mid hills of Nepal. It also indicates key areas for future research for the utilisation and improvement of existing fodder resources during the fodder deficiciency periods.

8.1 Feed availability and nutritional status of farm animals

Fodder was offered by farmers to their livestock according to availability, palatability, cost and experience of what seems to work in practice. Feeding practice was fairly consistent across the mid hills but varied slightly amongst individuals and genders and more so amongst locations with differing access to roads, markets and forest. The relative significance of different fodder resources was influenced by a number of factors, most notably the season and accessibility to markets. Farmers maintain varieties of trees and shrubs on their farmlands, especially those that are preferred for multiple outputs. Tree fodders are the most important source of protein and energy for farm animals and are important fresh material to supplement dry roughages in the diets of farm animals particularly during the dry season. The supply of tree fodder appeared to be sufficient to meet the dry matter requirements of the current livestock population in accessible sites such as Fikkal in Ilam district. However, a large proportion of this fodder was derived from the residues of broom grass after flower harvesting for commercial purposes, and thus had a low feeding value. Other sites, which have insufficient long-term fodder supply, should be encouraged to plant more fodder trees with desirable qualities. Private or government agencies with objectives of improving animal production should take initiatives for the promotion of potential fodder tree species.

Farmers at accessible sites, particularly in economically successful areas such as Fikkal, supply additional cereal and oilseed products to their livestock during the dry season. However, in other locations, the supply of local concentrate was generally similar throughout the year. The amount of the local concentrate offered was lower at all study locations than the recommended amount. In terms of quality, the local concentrate was also low in protein and energy content except in Fikkal. The animals, especially in less accessible sites, might have problems of protein and energy supplies which suggest the need to routinely supply oilseed cakes and milled products where possible. Hence, there is a need for increased allocations of high quality feeds for most classes of livestock, and particularly to lactating animals in accessible locations where introduction of exotic crossbred animals is increasingly high.

8.2 Coping with dry season fodder deficiency

During the critical dry period, the farmers' knowledge system appeared to be crucial in making decisions for the management and use of available fodder resources. Farmers conserve crop residues, mainly rice straw, for dry season feeding but these were not available in sufficient quantities for all farmers whilst, conservation of dry grass was not common practice in the eastern mid hills. Farmers not only cultivated tree species that were high in nutritive value but also other tree species that appeared to be inferior in feeding value. Some trees were maintained because they were available for feeding during the dry season and others because of socio-cultural importance and differences in food acceptability amongst animal species.

As the farmers are able to adapt quickly to changing circumstances, they use species specific knowledge to plan feeding fodder from trees according to season and the class and productivity of farm animals in the best way that they can. Although, feeding of tree leaves was reported to be dependent on household circumstances, in times of emergency, farmers tend to feed whatever is available within reach to them, as they do not have much scope for choice whilst, lack of manpower also constrains selective feeding of tree species even when resources are plentiful. In general, farmers plan lopping regimes of tree fodders to suit their fodder demand and according to the leaf retentiveness of individual tree species while trying to balance the feed for their animals.

Although practices vary depending upon the fodder resource and animal holding size, animal stress due to feed shortage is avoided by seasonal calving, whereby female stock are mated during the period of the year which will ensure that the peak demand for forage during late pregnancy and early lactation will coincide with the flush of forage growth. Likewise, sales of surplus offspring are timed to avoid additional animal demand for fodder during the dry season. Migration of animals from one farm to another and to neighbours for exchange of manure and fodder is another important strategy followed by farmers to mitigate fodder deficiency problems. Due to shortage of fodder resources, animals are fed a mixture of *ramro* (palatable and nutritious) and *naramro* (less palatable and less nutritious) fodder types to improve intake and efficiency of utilisation of available feed resources. However, farmers ensure a supply of highly nutritious fodders for productive animals such as lactating or growing animals at time of fodder shortage.

8.3 Local criteria for evaluation and selection of tree fodder

Farmers have extensive knowledge about individual trees and their management that is a reflection of their day-to-day needs and the extent of their dependence on trees. They have complex systems for evaluating tree fodders, which depended on various socio-cultural, animal and management factors. They use various terminologies to signify and differentiate fodder quality attributes. In addition to the *posilopan* and *obhanopan* criteria used by farmers to evaluate fodder quality previously reported (Thapa *et al.*, 1997), this study discovered another important term, '*adilopan*', the literal meaning of which is 'duration of appetite satisfaction'. Although, *adilopan* was found to be broadly used in association with the term '*obhanopan*', there were differences between the two in terms of palatability and milk or butterfat productivity of lactating animals. The farmers were valuing more *adilopan* (less digestible feeds), because they satisfied animal appetite for longer, thereby controlling hunger behaviour, a major objective at times when fodder is scarce. Besides fodder value, the fuel property and manure quality of tree species were the other important characteristics considered by farmers for the selection of tree fodders. Trees were graded into three categories according to fuel value, *kharopan* (desirable), *kafalopan* (less desirable) and *pochopan* (undesirable).

Similarly, they distinguished the manure quality by three different grades, *tikau mal* (desirable), *kam tikau mal* (less desirable) and *rukho mal* (undesirable), which they differentiated by compactness, decomposability of dung that the animals produce and the ability of manure for maintenance of soil fertility and sustenance of crop productivity.

8.4 Consistency in farmers' tree fodder evaluation

In general, farmers were consistent in their classification, ranking and evaluation of *posilopan*, *obhanopan* and *adilopan* towards the extreme ends of the rank scale (i.e. best or worst), while tree species intermediate in these attributes were less consistently ranked. Rankings for *posilopan* were clearly different from those for *obhanopan* or *adilopan*. Generally farmers' ranking of *posilopan* was based on its implications for health and productivity of animals whilst *adilopan* was found to correspond closely to *obhanopan* but was more associated with the digestibility of tree fodder.

The *obhanopan* attribute was seasonally dependent as the *posilopan* ranking of *obhano* fodders was reported to vary from *kamposilo* with changes in season and leaf maturity. *Obhano* or *chiso* fodder were not necessarily related to *ramro* (good) or *naramro* (bad) quality attributes as the latter attributes were reported to change with season or weather conditions. As a result, farmers' feeding and management plan could vary even in a day and according to variations in the microclimate of their farms, although this differed with individual circumstances.

8.4.1 Correspondence between local quality attributes and *in-vivo* or *in-vitro* measurements

Obhanopan

Broadly, palatability of tree fodder was found to be associated with the farmers' *obhanopan* criterion of fodder evaluation. *Chiso* fodders were more palatable than *obhano* fodders to all categories of animals when animals were offered a mixture of fodder types. However, *obhano* fodders were generally less preferred by goats whilst cattle and buffalo showed no marked preference. Farmers perceptions of palatability were associated with temperature to the extent that they asserted that in cool temperatures animals prefer *obhano* fodder but when warm they prefer *chiso* fodder, oats. No obvious differences were found in the preference of *obhano* fodders between hungry and full animals. It is anticipated that palatability is influenced not only by the presence of naturally occurring substances in the fodder, but also by other factors such as habitual adaptation to food, feeding management and grazing environment. Trials where intake of predominantly *chiso* or *obhano* fodder were compared at morning and afternoon feeding times might yield different results.

Adilopan

Under sole feeding conditions, intake of *obhano* fodders was generally higher than *chiso fodders* for all animal types. Although the fodder was supplied in excess of intake, the intake did not seem to be enough to completely fill the animals. The proportional intake rate was lowest in goats than other animals, which reflected difference in the eating habits of animals. Except in goats, there was slight positive association between the time taken to consume fodders and the duration that appetite was satisfied for, i.e. the longer the time required to chew, the longer was the appetite satisfaction of animals. Farmers' perceptions for *adilopan* generally agreed with the present findings that *adilo* fodder, satisfied appetite of animals longer than either *chiso* or *kamadilo* categories of tree fodders. This distinction is useful for research aimed at helping farmers during the dry season for effective and efficient use of farmland fodder resources in the mid hills of Nepal.

In vitro measurement of gas production suggested that *adilopan* is not strictly dependent on the fraction of food that is rapidly degraded in the rumen. This was also true for the relationship with the rate of degradation. However, there was evidence of a strong negative association between *adilopan* and potential degradability i.e. the lower the potential degradability, the higher the *adilopan* value.

Posilopan

Farmers' selection of tree species was related to their practical experience of feeding trees to animals and the resultant visible impacts on performance of their animals and the intended outputs, whether it is for milk or butterfat or both. Farmers' knowledge could reasonably differentiate between the most *posilo* and the most *kamposilo* tree species in terms of milk and butterfat yield responses in lactating animals. As the final outcome of the intended product depends on a combination of feeds and other factors such as the animal's potential for milk or butterfat production, local management practices and the environment, conflicting understanding was observed in some cases where there were small differences in response to feeding of tree fodders. Farmers' preference ranking for *posilopan* of tree fodders was however explainable broadly with animal responses in terms of milk and butterfat productivity, more so for milk yield that farmers could readily observe. Visible differences in health condition of the experimental animals suggest that farmers' evaluation criteria might combine productive attributes and health. This understanding however, has given potential scope for appropriate combination of farmers' knowledge with a biological basis for the improvement of livestock productivity in the hills of Nepal.

In vitro measurements suggested that crude protein (CP) and other protein fractions (soluble protein, total available protein) are important nutrients and are closely related with the *posilopan* attribute of tree fodder. However, compared to other protein fractions, the net protein that is available (per 100g of CP) to the animal has shown stronger correspondence with *posilopan*. This suggested that Nepalese ruminant animals require both the soluble protein for rumen environment and the rumen-escape protein for tissue synthesis; these attributes have been collectively recognized by farmers as *posilopan*.

Farmers' interpretations that mature leaves are more *posilo* than over-mature leaves were shown to be valid, but relatively higher concentrations of crude, soluble and available protein in young leaves were in contrast with farmers' perception that these leaves are *kamposilo*. The presence of higher amounts of condensed tannins but proportionally lower amounts of total extractable polyphenolics in young leaves compared to either mature or over mature leaves suggested a possible explanation for farmers' considering young leaves to be *kamposilo*. Since some *posilo* fodders (*malbans, badahar*) were generally less affected by Polyvinyl polypyrrolidone (PVPP) treatment compared with *kamposilo* tree fodders (*gogun*), this suggested for a possible association between *posilopan* and tannins. The presence of a relatively higher level of condensed tannins in *posilo* fodder species supported an association between *posilopan* and the protein fraction that is available in the duodenum.

8.5 Overall conclusion

Farmers in the eastern hills of Nepal possess explanatory knowledge on tree fodder evaluation and a complex knowledge system that allows them to tackle with the constraints of their environment and use the available resources in the best way that they can. When selecting a tree species for feed planning, although, practices may vary slightly amongst individuals, gender and locations, fodder is offered by farmers according to availability, palatability, cost and experience of what seems to work in practice. Farmers' judgements on the nutritional quality of tree fodders were related not only with multiple nutritional characteristics and their combined effect on animals (feed intake, digestibility, nutrient availability, productive parameters and control of animal behaviour) but various other socio-cultural and environmental factors rather than on a single compound creating a complex for providing decision support. Farmers' knowledge for the evaluation of fodder quality and its equivalence has been to some extent confirmed in terms of effects on animal performances and chemical terms. The study has given opportunities to identify ways to help farmers for effective and efficient utilisation of farmland fodder resources during fodder scarcity period of the dry season in the mid hills of Nepal.

8.6 Recommendations for future research

8.6.1 Improvement in nutrition of farm animals

More study needs to be geared towards introduction of better and more economical utilization of agricultural by-products, so that all the feed ingredients including roughages, local concentrates and other nutrients be utilised to meet the nutritional requirements of different categories of livestock for different physiological functions for the benefit of all categories of farmers in the hills.

Introduction of exotic cow breeds and their crosses has resulted in the establishment of farms with capability of very high lactation yield in certain market-accessible areas in the hills and urban areas of the country. These animals require special attention, which is normally ignored by the farmers due to their lack of knowledge of the general and specific nutritional requirements, resulting in inefficient production of milk. Undoubtedly feeding of lactating cows is an art, but for success it is important to know and to practise some well-established scientific principles in animal nutrition. Organised feeding becomes more important as most of the total cost of milk production goes towards food costs. The role of extension workers becomes crucial in helping dairy farmers on the nutrient requirements of the animals, the properties and feeding value of common foods and bringing these two aspects together for more profitable milk production.

The concept of nutritive value is related to the energy and protein status of the fodder provided the supply of essential minerals is adequate. The balance of nutrients required by the animal is set by its physiological state, which is high for pregnant and lactating animals and low for dry stock (Poppi *et al.,* 1997). The first need is to ensure that the rumen is functioning adequately in terms of intake of forage being processed and digested. The contribution of microbial protein depends upon the energy supplied in the diet and the availability of nitrogen from the rumen degradable protein (RDP) content of the food. Therefore, a good deal of attention requires to be given to the intake and digestibility of feeds. Farmers in market-accessible areas whose objectives would be to increase marketable milk production should provide highly nutritious and digestible fodder for rapid conversion of food into milk. However, they need to be made aware of the economic returns from the additional supply of highly nutritious feeds and fodder.

The overall extent of utilisation of trees and shrubs as fodder in smallholder mixed farming systems is still limited. Despite the fact that some 250 species of trees and shrubs are utilised for animal fodder throughout the whole year in the Nepalese hills, only about 15 tree species are commonly available to farm households for feeding at the peak time of feed scarcity. This means that farmers are forced to feed low quality crop residues to their animals. Since these feedstuffs are inadequate nutritionally by themselves, special attention should be given to improve the feeding value and efficient use of these low quality feedstuffs to the animals. Urea treatment or supplementation is widely used in other countries in south East Asia. Farmers should be advised to utilise urea-treated rice straw and supplement grasses and legumes to improve voluntary intake of roughages. Future strategies for improved utilisation of animal feeds need to be identified that are based on a knowledge of the availability and potential nutritive value of feeds, the production objectives and the production systems themselves. These strategies should promote the development of appropriate technology that can be adopted readily at the farm level. Emphasis needs to be given to the greater use of multipurpose trees, improved feed conservation and supplementation strategies. Feeding systems should be developed that synchronise feed availability with the nutritional requirements of animals throughout the year.

8.6.2 Integrated approach to address farmers' problems

While farmers in the hills of Nepal have depth of knowledge on the use of fodder trees, their efforts need to be backed up by technical and financial support. If such support is made available, the farmers may be able to increase their fodder resources and thereby become self-sufficient. Farmer to farmer extension networks should be developed and the research should be linked with extension services for better implementation. It is important that livestock extension work is fully backed by the national research system.

To increase on-farm forage supply, fodder trees that grow faster and provide fodder for longer period of time should be preferred over those that grow slowly and yield less fodder. Sound livestock and livestock product marketing, and live animal trade centres should be established to provide easy market access to farmers. Improvement in livestock productivity and the livestock production system through better feeding, breeding, health care, husbandry practices and the management of available resources at hand are key elements to improve the welfare of different socio-economic groups of people of different agro-ecological zones.

Beside the use of trees for fodder as a dietary supplement for livestock in the dry season, farmers should be encouraged to use firewood and timber as secondary products, which may be obtained from fodder trees as well as other trees growing on uncultivated farmland. If appropriate species are planted and harvested in the correct sequence, there are possibilities that green fodder could be harvested throughout the dry season. It is therefore important that the extension agents and local farmers should make efforts to put this system into effect. Under the present hill conditions, use of land is becoming more competitive to reconcile requirements for human food and animal fodder together with other requirements, for example for fuel and timber. If these requirements are not met on a rational basis, efforts to improve livestock productivity in isolation from other land uses will have very little meaning. Therefore, there is a need to adjust the balance between food, wood, animal fodder and other components in the complex farming system so as to sustain land use in an organised manner.

Most research projects are focused on trees in isolation, rather than in interaction with the other components of agroforestry systems such as fuel, timber and non-timber products, thus requiring more work in this aspect through participation of the local farmers. The Nepal Agroforestry Foundation (NAF), Centre for Environmental and Agricultural Policy Research Extension and Development (CEAPRED) and several organisations such as Social Action for Grassroots Organisation (SAGUN) are actively trying to bridge the seasonal gaps in fodder supply. However, the farmers or their groups should be encouraged to use their own initiatives to fulfil their objectives rather than become over-reliant on external support.

The commonly cited problems in milk production included low milk price, lack of market, lack of highly nutritious feed, lack of green fodders and lack of animal health services. The government, livestock specialists, extension agencies and agencies with interest in livestock promotion in Nepal should take initiatives jointly to address these problems.

8.6.3 More research on animal response studies

The dry matter intake of animals in this study was higher than the western standard, which needs to be re-confirmed under on-farm conditions using small numbers of animals over two major seasons. The higher level of protein and proportionally lower amount of energy in the diet of local animals observed in this study also needs to be re-examined.

Farmers are generally interested in increasing milk and butterfat production. Since the milk price is fixed based on the fat content of milk, farmers desire milk with high butterfat content. This simply means that farmers need to supply additional cereal grains. To avoid competition with the human population for cereal grains, there is a need to make the maximum use of low quality roughages and other locally available fodder resources. More frequent feeding is one way, which may spread out the load on the rumen environment for favourable butterfat content in milk. More research is needed in these areas.

Observing the variation in the amount of intake of tree fodders in the voluntary intake study, it was noted that intake was not enough to completely fill the animals under sole feeding conditions although the fodder was supplied in excess of intake. Hence, it is necessary to experiment on a large number of animals with tree fodders with varying levels of adilopan quality. Contrary to the expectation that hungry animals are less selective (Van Soest, 1983), no difference was observed in fodder preference between hungry and full animals. However, before general conclusions can be drawn from this observation, more extensive studies need to be done with a greater number of animals over a longer experimental period. Animals expressed a pattern of changes in the preference order of tree fodders over the experimental period. This suggested the necessity of consideration of a feeding period longer than five days to better characterise palatability and ingestibility of individual tree fodders.

More feeding trials need to be carried out in which relationships between varying levels of rumen by pass protein derived from tree fodders and animal response could be correlated. Alternatively, the farmers in areas with potential in milk marketing and accessibility to feed supplements should be instructed to slowly increase the level of oil seed meal until they are satisfied with the response. This would help farmers understand the animal response and guide them automatically to take the most economic option. However the role of extension agents would be crucial in this process.

8.6.4 Tannins and their impact on animal nutrition

About 16% of the available tree species commonly eaten by ruminants in Nepal have leaves containing levels of tannin which are thought to have deleterious effects to animals. Low to moderate levels of tannins are known to have some positive effects on nutritive value of feeds and fodders by preventing bloat and limiting extensive proteolysis or deamination in the rumen (Makkar and Goodchild, 1996). Recently a moderate level of tannin in the diet of ruminants has been reported to play a significant role in reducing negative effects of gastrointestinal helminth burdens (Kabasa *et al.*, 2000) and so improve nutrition of ruminant animals (Muellar-Harvey and McAllan, 1992, Subba *et al.*, 2000). Further experimental evaluation of tree fodders are needed for comprehensive understanding of the role of tannin in improving animal nutrition. A proper understanding of tannin properties and management options relating to this could help to utilise the protein and other nutrients in tree leaves in better way without adversely affecting the performances of farm animals. Lignin, another polyphenolic, is characterised by its ability to protect cell contents from digestion and this may act to increase retention time of the food in the rumen. Leaf polyphenol contents are not reliably predictable and may increase or decrease with age, depending on the tree species, and comprehensive understanding of their properties for animal nutrition requires future research.

Despite a low content of anti-nutrients (tannins) and high content of nutrients (proteins), the low rank of *painyu* in terms of *posilopan* and its rejection as a fodder needs to be further investigated. Although cases of poisoning and death under *ad libitum* feeding of young *painyu* leaves have been reported (SN Mahato, Director General, Department of Livestock Service, unpublished data), further investigation under practical feeding situations needs to be explored together with the investigation of a condition often reported by farmers as *lahumute* (literal meaning is red coloured urine) when painyu is fed to draught animals. This condition requires investigation to see whether it is associated with economically significant bovine haematuria or is simply a plant pigment in urine.

8.6.4.1 Detoxification of tannins

This study was limited to tree species that contained tannins to a maximum of about 6% (in dry matter),which is at or below the maximum tolerable limit (<5% condensed tannin) in large ruminants. However, more research is needed to understand tannin chemistry and its detoxification processes before the technologies are recommended to the end users.

Little is known about optimum dietary levels of feeds from individual shrub and tree species, about alleviating the incidence of deleterious effects, and about suitable mixtures in economic feeding systems for individual ruminants. Strategies to detannify tannin-rich tree leaves and browses using simple and economically viable approaches are important so that local farmers can gain the full benefits of nutrient-rich tanniniferous plants. Efforts have been made by various workers to ameliorate the deleterious effects of tannin-rich animal feeds (Palmer and McSweeney, 1999; Makkar, 2001) with the use of protein complexing agents such polyvinylpolypyrrollidone (PVPP) or polyethylene glycol (PEG) in the diet of animals in situations where animals are to be maintained on tannin-rich fodder. However, using complexing agents in routine feeding may not be economic. It is likely that microbial adaptation may be the primary mechanism by which ruminants can tolerate high levels of tannins in their diet. A better understanding of the mechanism of tannin utilisation by animals will be necessary to manipulate tannins in feeds and fodder through selection of plant species or simulating microbial degradation. More research is required on the feasibility of detannification in farmers' socio-economic conditions.

8.6.5 Promoting low tannin-content fodder tree species

The negative effects of tannins could be avoided by selecting fodder species with low tannin content. Particular attention needs to be paid when feeding high tannin content tree species so as to avoid possible ill effects to animals. However, the positive role of tannins in delivering protein to the duodenum should not be ignored. Supply of nutrients by tree fodder could be improved through proper combinations of suitable fodder resources. Tree fodder that was inherently low in palatability, might be made acceptable through supplementation with other fodder species, which are highly palatable. The choice of tree fodders should be made in such a way that the resources are utilized to promote maximum animal productivity with minimum supply of inputs and the tree fodder production and improvement programmes should ensure year-round fodder availability and high animal productivity. The government and NGOs who are encouraging farmers to plant more tree fodders should take initiatives to promote fodder species containing higher nutritive values and lower anti-nutrients. However, extensionists or other related personnel who are directly or indirectly responsible for promoting animal productivity should create awareness among farmers about the potential risk of anti-nutrients and importance of the plant species containing higher levels of nutrients.

8.6.6 Manure quality

In general, the livestock population in the hills of Nepal is declining. This reduction may cause problems in sustaining crop production because of a decrease in the amount of manure available. Farmers mix tree fodders to feed to the animals from widely differing fodder species. The quality of manure produced from feeding mixed fodders needs to be evaluated in terms of its nutrient decomposition rate and nutrient availability over time. This is a subject, which has received little attention to date. In terms of maintenance of soil fertility, a slow decomposition rate is the characteristic most desired by farmers. Slow decomposition rate could result from several different factors, generally related to large amounts of reactive polyphenols or structural lignin and associated insoluble proanthocyanidins (Mafongoya *et al.,* 1998). Information about polyphenolics in agroforestry trees and their role in decomposition might be gained by examining the data on condensed tannins in tree fodder and their effect on feed digestibility and nitrogen release. Mafongoya *et al.* (1998) reported that 15% lignin is a critical level, above which decomposition of organic matter is impaired for plant materials. Research has yet to be carried out to quantify the association of nutrients with lignin. Interactions between nutrient availability in the animal or plant system and plant polyphenolics might be complex. However, to fully understand the manure value of tree fodders, the role of polyphenolics needs to be understood in greater detail.

8.6.7 Linking farmers' and scientific knowledge

This study has given potential scope for bridging knowledge gaps with appropriate combination of farmers' knowledge (about a wide range of tree species) with biologically-based technical data for the development of flexible decision support tools for the improvement of livestock productivity in the hills of Nepal. Development of effective mechanisms appears to be essential for linking the farmers' and scientific knowledge to address the problem of feed and nutrition during the dry season. Such an approach is currently under development. Preliminary attempts (Thorne *et al.,* 2000) to integrate scientific information on the biology of animal feeding with the wide-ranging and effective indigenous knowledge base of the farmers in a model, showed that model predictions of the effects of feeding strategies used by farmers were consistent with the farmers' expressed objectives of milk production while ensuring that animal appetite remained adequately satisfied in times of feed shortage. Further study requires collection of data on farmers' fodder quality evaluations for a broader range of tree species, together with collation of scientific data on a broader range of tree and livestock management information.

Farmers have substantial knowledge and management capability relating to animals and fodder trees. It is necessary to develop feeding systems on the basis of what farmers already know. Therefore, any attempts by government or development agencies to intervene in natural resource management should be done on the basis of knowledge of what is already known by the farmers. Research on the management and use of tree fodders is limited, although their potential is increasingly being recognized. Priority must be given to highly preferred trees with values in relation to animal, socio-cultural, and environmental importance. Much information is required on feeding behaviour, palatability, animal productivity, management systems, tolerance to and the effects of deleterious dietary principles.

REFERENCES

Acasio, R.N., Castillo, A.C. and Victorio, E.E. (1999). Palatability of new Leucaena to sheep. Proceedings of the regional research and development symposia, Los Banos, Laguna, The Philippines

Ahmed, M. and Butt, N.M. (1994). Implications of grazing on range livestock production. Progressive farming. Pakistan Agricultural Research Council, Islamabad. 14 (1), pp56-61

Albright, J.L. (1993). Feeding behaviour of dairy cattle, *Journal of dairy science*. 76 (2), pp485-498

Alm, U., Birgersson, B. and Leimar, O. (2002). The effect of food quality and relative abundance on food choice in fallow deer. *Animal behaviour*, 64, pp439-445

Anderson, J.M. and J.S.I., Ingram (1989). *Tropical soil biology and fertility*: a hand book of methods C.A.B. International, Wallingford, UK

Anderson, P. (2001). Geographical approaches to micronutrient deficiencies in Himalaya, In: Vegetation and Society: Their Interaction in the Himalayas (eds: Chaudhary, R.P., Subedi., B.P., Vetaas, O.R. and Aase, T.H.), *Proceedings of the workshop on Bergen-tribhuvan human ecology programme*, Nov 25-27, Kathmandu, Nepal

Anon (1986). Report on livestock statistics of Nepal. Agricultural Statistics Division, Department of Food and Agricultural Marketing Services, Kathmandu Nepal, pp122-136

Anon (1990). A study on dairy farmers in Nepal, a report submitted to Carl Bros International a/s, Granskoven 8, DK-2600 Glostrup, Denmark, New Era, Maharajgunj, Kathmandu

Anon (1993). Energy and protein requirements of ruminants. An advisory manual prepared by the AFRC technical committee on responses to nutrients. CAB International, Wallingford, UK

Anon (1996). Nepal living standards survey report, Main Findings vol. 2., Central Bureau Of Statistics, National Planning Commission Secretariat, HMG (N), Kathmandu, Nepal

Anon (2000a) National accounts of Nepal, HMG (N), National Planning Commission Secretariat, Central Bureau of Statistics, Kathmandu, Nepal

Anon (2000b). Statistical Information On Nepalese Agriculture (1999/2000), HMG (N), Ministry of Agriculture and co-operatives, Agri-business promotion and statistics division, Kathmandu, Nepal.

Antweiler, C. (1998). Local knowledge and local knowing-an anthropological analysis of contested "cultural products" in the context of development. Anthropos, 93(4-6), pp469-494

AOAC (Association of Official Analytical Chemists) (11th edition) (cited by Egan, H., Kirk, R. S. and Sawyer, R. 1981). *Pearson's Chemical Analysis of Foods*, eighth edition, Churchill Livingstone.

Arnold, G.W. (1964). Some principles in the investigation of selective grazing. *Proceedings of the Australian society of animal production*, 5, pp258-271

Aryal, I.K. and Gurung, H.B. (2000). Effect of time of planting on fodder production of oats under rainfed condition. In: Sherchand, L., Pradhan, B.R., Bhurtel, R. and Neopane, S.P. (eds) Proceeding of the workshop on *Environmentally sustainable livestock production for poverty alleviation*, Nepal Animal Science Association, Kathmandu, Nepal August 27-28, 1997

Aryal, S.R. and Singh, U.M. (1999). Collection and identification of poisonous plants in mid-western region of Nepal. *Veterinary Review*, 14, pp26-28, Kathmandu, Nepal

Bajracharya, J. (1985). Effect on intake and milk yield of cows fed urea-treated paddy straw. *Nepalese Journal of Animal Science*, 2 (1)

Balaraman, N. (1996). Process of making Nebharo (*Ficus hookeri*) hay and its nutritive value for goats, *Indian Journal of Animal Nutrition*. 13(4), pp204-208

Banstola, B.R. and Shrestha, N.P. (2000). Study on forage conservation for winter-feeding in Langtang VDC of Rasuwa district In: Singh, S.B., Aryal, I.K. and Rai, A.K. (eds). *Proceedings of the 4th National Animal Science Convention*, Nepal Science Association (NASA), Kathmandu, Nepal

Basnyat, N.B. (1989), Report on pasture and rangeland resources in upper mustang, consultant's report. United nations development program, Pasture and fodder development in the high altitude zone, Kathmandu.

Baumont, R., Prache, S., Meuret, M and Morand-Fehr, P (2000). How forage characteristics influence behaviour and intake in small ruminants: a review. *Livestock Production Science*, 64, pp15-28

Begovic, S., Dysic, E., Sacirbrebegovic, A and Tafro, A. (1978) (Cited by Silanikove *et al.* 1996): (Examination of tannase activity of ruminal content and mucosa of goats on oak leaf diet and during intra ruminal administration of 3-10% tannic acid). Veterinaria (Sarajevo), 27, pp459-485 (Serbian with English summary).

Carter, A.S. and Gilmour, D.A. (1989). Increase in tree cover on private farmland in central Nepal. *Mountain Research & Development,* 9(4), pp381-391

Carter, E.J. (1992). Tree cultivation on private land in the middle hills of Nepal: lessons from some villagers of Dolakha district. *Mountain Research & Development*, 12 (3), pp241-255

Chambers, R. (1987). Agricultural research for resource-poor farmers. Part II: A parsimonious paradigm. *Agric admin & extension*, 27(1987), pp109-128

Chambers, R. (1992). Rural appraisal: rapid, relaxed and participatory. IDS Discussion paper 311.

Chapa, D.R. (1994). Fodder and desirable characteristics prioritisation exercise in Kapurkot, Dhanabang VDC of Salyan. *Banko Janakari*, 4(2), Kathmandu

Cheeke, P.R (1985). *Natural toxicants in feeds and poisonous plants*. The AVI publishing company, USA.

Chemjong, P.B. (1989). Economic value of urea treated straw fed to lactating buffalo during the dry season. PAC Technical paper no 110, Pakhribas Agricultural Centre, Dhankuta, Nepal

Chemjong, P.B., Kshatri, B.B., Shrestha, S.R. and Rai, P.P. (1990). Supplementation of straw-based diets for lactating buffaloes in the eastern hills of Nepal. PAC Technical paper 123. Pakhribas Agricultural Centre, Kathmandu

Chen, X.B. (1995). A utility for processing data of feed degradability and in vitro gas production. Rowett Research Institute, Aberdeen, Scotland

Conlin, S. and Falk, A. (1979). A survey of the socio-economy of the Koshi hills area: guidelines for planning an integrated rural development programme. KHARDEP. Report No 3, Koshi Hills Regional Development Project, Dhankuta, Nepal

Cooper, S.M. and Owen-Smith, N. (1985). Condensed tannins deter feeding by browsing ruminants in a South African savannah, *Oecologia* (Berlin), 67, pp142-146

Dahiya, S.S., Punia, B.S. and Chauhan, TR (1998). Voluntary feed intake and nutrient utilization in buffalo bullocks fed untreated and urea (ammonia) treated berseem and oat straws. *Indian Journal of Animal Nutrition*, 15(2), pp93-96

Dawra, R.K., Makkar, H.P.S. and Singh, B. (1988). Total phenolics, condensed tannins and protein precipitable phenolics in young and mature leaves of oak species. *Journal of Agriculture and Food Chemistry*, 36, pp951-953

Devendra, C. (1989). The use of shrubs and tree fodders by ruminants. In: Devendra, C. (ed). *Shrubs and tree fodders for farm animals*. Proceedings of a workshop in Denpasar, Indonesia

Devkota, N.R., Sapkota, M., Yadav, J.L., Pant, S.S. and Pande, K.R. (1995). Indigenous management and nutrient analyses of fodder trees and feed mixtures in Chitwan. Institute of agriculture and animal sciences reports (ed: F P Neupane), Tribhuvan University, Chitwan, Nepal

Dewalt, B.R. (1994). Using indigenous knowledge to improve agriculture and natural resource management. *Human Organization*, 53(2), pp123-131

Dhakal, L.P. and Lilleso, J. P. B. (2000). Fodder domestication issues and use of potential vegetation map in increasing fodder production in the mid-hills of Nepal. Proceeding of the national level workshop on improved strategies for identifying and addressing fodder deficits in the middle-hills of Nepal, 5-6th September, Kathmandu, Nepal.

Dhaubhadel, T.S. (1992). Comparison of the effect of feeding lactating cattle with straw treated with 4% urea and straw with cattle urine, Working paper no 92/44, Lumle Regional Agricultural Research Centre, Pokhara, Nepal

Dhaubhadel, T.S. and Tiwari, B.N. (1991). Problems and prospects of crop by product utilisation as animal feed in the hills of Nepal: experience of Lumle regional agricultural research centre, Nepal. In: Romney, D.L, Ørskov, E.R. and Gill, M. (eds). *Workshop proceedings of the utilisation of straw in ruminant production systems*. 7-11 October, Malaysian Agriculture Research and Development Institute (MARDI), Malaysian

Dhungana, R.P., Shrestha, K.P., Tripathi, M.P. and Bhattarai, T.N. (1998). Site selection, household categorization and problem identification in Fikkal outreach research site, Ilam. Agricultural Research Station, Pakhribas, Dhankuta, Nepal

Dicko, M.S. and Sikena, L.K. (1991). Feeding behaviour, quantitative and qualitative intake of browse by domestic ruminants. In: Speedy, A. and Pugliese, P. (eds) *Proceedings of the FAO expert consultation* held at the Malaysian agricultural research and development institute (MARDI) in Kuala Lumpur, Malaysia, 14-18 October.

Dixit, V.B., Manuja, A. and Chauhan, T.R. (2000). Farmers' rationale of indigenous buffalo husbandry practices in Haryana. *Indian Journal of Dairy Science*, 53 (4)

Dixon, H.J., Doores, J.W., Joshi, L and Sinclair, F.L. (1999). Agro-forestry knowledge toolkit for windows (winAkt): Methodological guidelines, computer software and manual, University of Wales, Bangor.

ECONOMIC SURVEY, fiscal year 2000/2001, His majesty's government ministry of finance (2001)

EPC (1993). Environmental Protection Council Nepal. Environmental Policy, A compendium on the environmental statistics of Nepal, HMG, NPC Secretariat, Kathmandu, Nepal.

Faint, M.A., McNeill, D.M., Stewart, J.L., Castillo, A.C., Acasio, R.N. and Lynch, J.J. (1998). In: Shelton, H.M., Gutteridge, C., Mullen, B.F. and Bray, R.A. (eds). Palatability of Leucaena to ruminants. Leucaena-adaptation and farming systems Proceedings of a workshop held in Hanoi, Vietnam

Fisher, R.A. and Yates, F. (1963). Statistical tables for biological, agricultural and medical research, 6th edition, Oliver and Boyd, Edinburgh

Fonzon, P.F. and Oberholzer, E. (1984). Use of multipurpose trees in hill farming systems in western Nepal. *Agroforestry Systems*, 2, pp187-197

Forbes, J.M. (1998). Dietary awareness. *Applied Animal Behaviour Science*, 57, pp287-297

Fujisaka, S. (1989). A method for farmer-participatory research and technology transfer: upland soil conservation in the Philippines. *Expl Agric*, 25, pp423-433

Fujisaka, S. (1994). Learning from six reasons why farmers do not adopt innovations intended to improve sustainability of upland agriculture. *Agricultural Systems*, 46 pp409-425

Gatenby, R.M., Mahato, S.N. and Shrestha, N.P. (1989a). Animal production in the hills of east Nepal: Potential for improvement. PAC Technical paper 112. Pakhribas Agricultural Centre, Dhankuta, Nepal

Gatenby, R.M., Neopane, S.P. and Chemjong, P.B. (1989b). Traditional feeding practices for buffaloes in the Koshi hills. PAC Technical paper 99. Pakhribas Agricultural Centre, Dhankuta, Nepal

Gatenby, R.M., Thapa, B. and Shrestha, N.P. (1990). *Livestock in the hills of Nepal*. Proceedings of an international conference, Pakhribas Agricultural Centre, Dhankuta, Nepal

Gilmour, D.A. (1997). Rearranging trees in the landscape in the middle hills of Nepal. In: Arnold, J.E.M. and Dewees, P.A. (eds). *Farms, trees and farmers: responses to agricultural intensification*. Earth scans Publications Ltd, London.

Gilmour, D.A. and Nurse, M.C. (1991). Farmer initiatives in increasing tree cover in central Nepal. In: workshop on socio-economic aspects of tree growing by farmers, Institute of rural management, Anand, Gujarat, India

Greenhalgh, J.F.D. (1980). Use of straw and cellulosic wastes and methods of improving their value. In: Orskov, ER (ed). *By-products and wastes in animal feeding*. An occasional publication of the British society of animal production, No: 3, pp25-31

Gupta, B.N., Chatterjee, D., Chaudhari, A.B. (1982). Note on trace element status of feeds and fodders in milk-shed areas of Gauhati-Shillong. *Indian Journal of Animal Sciences*, 52, pp569-572

Gurung, H.B., Acamovic, T. and Stewart, C. (1993). Effect of tannin on the rumen degradability of the fodder tree leaves. *Veterinary Review*, 8(1), pp14-16

Gurung, H.B., Gatenby, R.M., Neopane, S.P., Shrestha, N.P. and Chemjong, P.B. (1989). Numbers of animals on farms in the Koshi hills. Technical Paper 109. Pakhribas Agricultural Centre, PO Box 106, Kathmandu, Nepal.

Gurung, S. (2001). Local ecological knowledge about management of tree fodder resources in the western mid hills of Nepal, MSc Thesis, Agricultural University of Norway, Norway

Hadjigeorgiou, I.E., Gordon, I.J. and Milne, J.A. (2003). Comparative preference by sheep and goats for Graminaeae forages varying in chemical composition. *Small Ruminant Research*, 49, pp147-156

Hagerman, A.E., Rice, M.E., Ritchard, N.T. (1998). Mechanisms of protein precipitation for two tannins, pentagalloyl glucose and epicatechin 16 (4>8) catechin (procyanidin). *J. Agric. Food Chemistry*. 46, pp2590-2595

Harborne, J. (1998). Phytochemical methods: A guide to modern techniques of plant analysis. Chapman & hall, London

Haque, M., Davis, C.H., Saadullah, M. and Dolberg, F. (1983). A note on the performance of cattle fed treated paddy straw with animal urine as a source of ammonia. Tropical animal production, 8:276-278

Hendy, C.R.C., Vickers, B., Chhetri, R., Basukala, R., Kharel, R., Regmi, B. N. and Kiff, E. (2000) Seasonal patterns of livestock feed collection and deficits on small-holder mixed farms in the mid-hills zone of Nepal. Paper to National Workshop on *Improved Strategies for Identifying and Addressing Fodder Deficits in the Mid-hills of Nepal*, 5-6 September 2000.

Heuch, J.H.R. (1986). Fodder for forester. Technical paper 86/3, Lumle Agricultural Centre, Kaski, Nepal

HMG (N), Ministry of Agriculture and co-operatives, Agri-business promotion and statistics division, Kathmandu, Nepal

Hodgson, J. (1986). Grazing behaviour and herbage intake. In: Framie, J. (ed.) *Grazing*, Occasional symposium no: 19, pp51-65, British Grassland Society, UK

Hoffmann, R.R. (1989). Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. *Oecologia*, 78, pp443-457.

Humphreys, L.R. (1991). *Tropical Pasture Utilisation*. Cambridge university press, Cambridge, UK

Jasra, A.W. and Iqbal, M. (1994). Implications of grazing on range livestock production. Progressive farming. Pakistan agricultural research council, Islamabad. 14 (1), pp39-43

Jayasuria, M.C.N. (1983). Problems of treating crop residues at the village level. In: The Utilisation of fibrous agricultural residues. Australian development assistance bureau research for development, Canberra, Australia pp100-106

Jayasuriya, M.C.N. (1985). Potential for better utilization of crop residues and agro-industrial by-products in animal feeding in the Indian sub-continent. FAO Animal Production and Health Paper, 50 pp 37-39

Johansson, B., Uvnas-Moberg, K., Knight, CH and Svennersten-Sjaunja, K (1999). Effect of feeding before, during and after milking on milk production and the hormones oxytocin, prolactin, gastrin and somatostatin. Journal of Dairy Research, UK, 66, pp151-163

Joshi, B.R., Kadariya, R.K., Karki, N.P.S. and Gurung, D.B. (1992) Milk production of local and 50% Jersey crossbred cows under farmers' traditional management in the western hills of Nepal. Working paper no: 1992/15, Lumle regional agricultural research centre, Pokhara, Nepal

Joshi, L. (1997). Incorporating farmers' knowledge in the planning of interdisciplinary research and extension. PhD Thesis, University of Wales, Bangor

Joshi, N.P. and Singh, S.B. (1989). Availability and use of shrubs and tree fodders in Nepal. In: Devendra, C. (ed) *Shrubs and tree fodders for farm animals*. Proceedings of a workshop in Denpasar, Indonesia.

Jung, H.G. and Fahey, Jr. G.C. (1983). Nutritional implications of phenolic monomers and lignin-a review. *Journal of Animal Science,* 67(1).

Kabasa, J.D., Opuda-Asibo, J. and ter Meulen, U. (2000). The effect of oral administration of Polyethelene glycol on faecal helminth egg counts in pregnant goats grazed on browse containing condensed tannins. *Tropical Animal Health and Production,* 32, pp73-86

Kaitho, R.J., Umuna, N.N., Nsahlai, I.V., Tamminga, S., Van Bruchem, J., Hanson, J. and Van De Wouw, M. (1996). Palatability of multipurpose tree species: effect of species and length on intake and relative palatability by sheep. *Agroforestry Systems*. 33, pp249-261

Kaitho, R.J., Umunna, N.N., Nsahlai, I.V., Tamminga, S. and Bruchem, J. Van (1998). Utilization of browse supplements with varying tannin levels by Ethiopian menz sheep. *Agroforestry systems*. 39, pp161-173

Karki, N.P.S. (1984). Livestock and feed resources in the hills of Nepal from the example of command areas of Lumle agricultural centre, Seminar paper, forestry workshop 24-27 January, Lumle, Gandaki, Nepal

Katuwal, S.R., Chudal, R.K. and Magar, H.B. (1998). Exercise on problem identification and prioritisation at outreach research site, Fakchamara, Terhathum. Agricultural Research Station, Pakhribas, Dhankuta, Nepal

Kayastha, B.P., Khan, M.H., Adhikari, S.N., Khan, S.N., Tiwari, K.R. and Shrestha, K.M. (1998). Dynamics of fodder tees in the middle hills of Nepal. In: Mathema, P., Dutta, I.C., Balla, M.K. and Adhikary, S.N. (eds) *Proceedings of an international seminar on sustainable forest management.* Institute of forestry/International tropical timber organization, Pokhara, Nepal

Khadka, R. and Gibbon, D. (1988). The contribution of Pakhribas agricultural centre to the development of farming system in the eastern hills of Nepal, PAC technical paper 111, Pakhribas agricultural centre, Kathmandu, Nepal

Khanal, R.C. and Rana, R.S. (2001). Effect of pre-treatment of crop residues on the nutrient composition and *in-situ* drymatter degradation in local male buffaloes. *Proceedings of the 4th national animal science convention Nepal animal science association (NASA)*, Lalitpur, Nepal

Khanal, R.C. and Subba, D.B. (2001). Nutritional evaluation of leaves from some major fodder trees cultivated in the hills of Nepal. *Animal Feed Science and Technology.* 92, pp17-32

Khanal, R.C., Panday, S.B. and Khanal, S.K. (1999). Feeding systems, feeds availability and nutrient content in the feeds and forages found in the high mountain areas of Solukhumbu and Sankhuwasabha district. Proceedings of 3rd national workshop on livestock and fisheries research in Nepal, NARC/NASA, Khumaltar, Nepal

Krueger, W.C., Laycock, W.A. and Price, D.A. (1974). Relationships of taste, smell, sight and touch to forage selection. *Journal Range Mange*, 27, pp258-262

Kshatri, B.B. (2000). Socio-economics and welfare in relation to environment: a case of cattle and its importance in the farming system of Hindu country Nepal. In: Sherchand, L., Pradhan, B.R., Bhurtel, R. and Neopane, S.P. (eds). *Environmentally Sustainable Livestock Production For Poverty Alleviation*, Nepal Animal Science Association, Kathmandu, Nepal August 27-28, 1997

Kumar, R. (1992). Anti-nutritional factors, the potential risks of toxicity and methods to alleviate them. In: Speedy, A. and Pugliese, P (eds). *Legume trees and other fodder trees as protein sources for livestock*, Proceedings of the FAO expert consultation held at the Malaysian Agricultural Research and Development Institute (MARDI), Kuala Lumpur, Malaysia 14-18 October 1991.

Kumar, R. and Vaithiyanathan, S. (1990). Occurrence, nutritional significance and effect on animal productivity of tannins in tree leaves. *Animal Feed Science & Technology.* 30, pp21-38.

Larbi, A., Smith, J.W., Kurdi, I.O., Adekunle, I.O., Raji, A.M. and Ladipo, D.O. (1996). Feed value of multipurpose fodder trees and shrubs in West Africa: edible forage production and nutritive value of *Millettia thonningii* and *Adbizia lebbeck. Agroforestry Systems*, 33, pp41-50.

Le Houerou, H.N. (1991). Feeding shrubs to sheep in the Mediterranean arid zone: intake, performance and feed value. IVth International rangeland congress, Montpellier, France

Mafongoya, P.L., Giller, K.E. and Palm, C.A. (1998). Decomposition and nitrogen release patterns of tree prunings and litter. Agroforestry Systems, 38, pp77-97

Mahato, S.N. (2000). Control of Fasciolosis in stall-fed buffalo by managing the feeding of rice straw. In: Mahato, S.N., Harrison, L.J.S. and Ghimire, S.C. (eds). *Proceedings of the workshop on Strategies for feed management in areas endemic for Fascioliasis*, pp 17-20

Mahat, T.B.S. (1987). Forestry-farming linkages in the mountains. Occasional paper No 7, *International Centre for Integrated Mountain Development*, p48

Mahat, T.B.S., Griffin, D.M. and Shepherd, K.R. (1986). Human impact on some forests of the middle hills of Nepal. Part 4. A detailed study in South East Sindhupalchok and North East Kabhrepalanchowk, *Mountain Research and Development*, 7(2), pp111-134

Mahat, T.B.S., Griffin, D.M. and Shepherd, K.R. (1987). Human impact on some forests of the middle hills of Nepal. Part 3. Forests in the subsistence economy of Sindhupalchok and Kabhrepalanchowk. *Mountain Research and Development*, 7 (1), pp53-70.

Makkar, H P S, Sing, B and Dawra, R K (1987). Tannin-nutrients interactions - a review. *International Journal of Animal Sciences*. **2**(2), 127-140.

Makkar, H.P.S. (1993). Antinutritional factors in foods for livestock. In: Gill M, Owen E, Pollot, G.E. and Lawrence T.L.J. (eds) Animal production in developing countries, Occasional publication No 16, pp69-85. *British Society of Animal Production.*

Makkar, H.P.S. (2001). Chemical, protein precipitation and bioassays for tannins, effects and fate of tannins, and strategies to overcome detrimental effects of feeding tannin-rich feeds. Paper presented at the 9th Seminar of the FAO-CIHEAM Sub-Network on Sheep and Goat Nutrition. Hammamet, Tunisia 8-10 November, Vienna, Austria

Makkar, H.P.S. and Becker, K. (1998). Do tannins in leaves of trees and shrubs from African and Himalayan regions differ in level and activity? *Agroforestry Systems*, 40, pp59-68, The Netherlands.

Makkar, H.P.S. and Goodchild, A.V. (1996). Quantification of tannins: a laboratory manual, Pasture, Forage and livestock program, International Centre for Agricultural Research in the dry areas, Aleppo, Syria.

Makkar, H.P.S., Dawra, R.K. and Singh, B. (1988). Changes in tannin content, polymerisation and protein-precipitation capacity in oak (*Quercus incana*) leaves with maturity. *Journal of Science Food and Agriculture*, 44: pp301-307

Makkar, H.P.S., Singh, B. and Dawra, R.K. (1986). Can oak leaves be fed to animals? *Farmers and Parliament* 24, pp17-18

Marten, G.C. and Andersen, R.N. (1975). Forage nutritive value and palatability of 12 common annual weeds. *Crop Science*. 15, pp821-827

Massdorp, B.V., Muchenje, V. and Titterton, M. (1999). Palatability and effect on dairy cow milk yield of dried fodder from the forage trees *Acacia boliviana, Calliandra calothyrsus* and *Leucaena leucocephala,* Animal feed science and technology, 77, pp49-59

McClure, G. (1989). Introduction In: Warren, S. and Titilola (eds.) Indigenous knowledge systems: Implications for agriculture and international development. Ames: Technology and social change program, Iowa state university, National research council (NRC), pp1-11.

McDonald, P., Edwards, R. A., Greenhalgh, J.F.D. and Morgan, C.A. (1995). *Animal Nutrition*. Fifth edition, Longman scientific and technical, New York.

McDowell, L. R. and Conrad, J. H. (1990). Mineral imbalances of grazing livestock in tropical countries. *International Journal of Animal Science,* 5, pp21-32

Mead, R., Curnow, R.N. and Hasted, A.M. (2003). Statistical methods in agriculture and experimental biology, 3rd edition, Chapman and Hall, London

Menke, K., Raab, L., Salewski, A., Steingass, H., Fritz, D., Schneider, W (1979). The estimation of digestibility and metabolisable energy content of ruminant feedingstuffs from the gas production when they are incubated with rumen liquor *in-vitro*. *Journal Of Agriculture Science*, Cambridge 3, pp217-222

Muellar-Harvey, I. and McAllan, A.B. (1992). Tannins: their biochemistry and nutritional properties. *Advance Plant Cell And Biochemistry And Biotechnology,* 1, pp151-217

Mueller-Harvey, I. (1989). Identification and importance of polyphenolic compounds in crop residues. *Animal Feed Science and Technology*, 45(7), pp215-218

Neopane, S.P. and Shrestha, N.P. (1991). Cultivation of two different varieties of berseem as winter fodder. *Veterinary Review*, Pakhribas Agricultural Centre, Kathmandu, Nepal

Ng'ambi, J.W.W. and Kekena-Monare, L. (1996). Improving wheat straw intake by goats, *African feed resources network (AFRNET) workshop*, Harare, Zimbabwe (Ndikumana, J. and Leeuw, P. (eds). *African feed resources network. Sustainable feed production and utilisation for smallholder livestock enterprises in sub-Saharan Africa*, Proceedings of a workshop, Nairobi, Kenya.

Niamir, M. (1990). *Community forestry: Herders' decision making in natural resources management in arid and semi-arid Africa*. Rome, Food and Agriculture Organizations of the United Nations.

Nocek, J.E. and Russek, J.B. (1988). Protein and energy as an integrated system: relationship of ruminal protein to carbohydrate availability to microbial synthesis and milk production. *Journal of Dairy Science*, 71, pp2070

Nuwanyakpa, M.Y. (1986). The effects of tannins on animal nutrition. *ARNAB News* letter. International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Oli, K.P. (1985). High altitude animal production system in the eastern hills of Nepal. Technical Paper no: 84, Pakhribas Agricultural Centre, Dhankuta, Nepal

Oli, K.P. and Shrestha, N.P. (1986). The use of urea treated straw in feeding lactating hill swamp buffalo. PAC Technical paper no 89, Pakhribas Agricultural Centre, Dhankuta, Nepal

Ologhobo, A.D. (1989). Mineral and anti-nutritional contents of forage legumes consumed by goats in Nigeria. In: Wilson, R. and Melaku, A. (eds). *African small ruminant development International Livestock Centre for Africa*, Addis Ababa, Ethiopia

Ørskov, E.R. (1998). *The Feeding Of Ruminants, Principles And Practice*. 2nd edition. Rowett Research Institute, Aberdeen, Scotland

Ortiz, O. (1999). Understanding interactions between indigenous knowledge and scientific information. Indigenous knowledge and development monitor (7)(3), visited on 31/07/2003 at site: http://www.nuffic.nl/ciran/ikdm/7-3/ortiz.html

Panday, K.K. (1982). *Fodder trees and tree fodder in Nepal*. Swiss Development Cooperation, Berne, Switzerland

Panday, S.B. (1989). Research needs in ruminant nutrition. In: Yazman, J.A. and Oli, K.P. (eds). *Proceedings on the workshop on research needs in livestock production and animal health in Nepal*. Khumaltar, Lalitpur, Kathmandu, Nepal

Panday, S.B. (1997), Technical report, Nepal Agricultural Research Council, Animal Nutrition Division, Khumaltar, Lalitpur, Kathmandu, Nepal

Pande, R.S. (1994). Livestock feed and grassland development in Nepal (*in Nepali*). National forage and grassland research centre, Kathmandu, Nepal

Pande, T. and Neupane, D.S. (1995). Learning Indigenous knowledge from farmers about fodder trees. Institute of agriculture and animal sciences reports In: Neupane, F.P. (ed)), Tribhuvan University, Chitwan, Nepal

Pearson, R.A. (1990). A note on live weight and intake and digestibility of food by draught cattle after supplementation of rice straw with the fodder tree *Ficus auriculata*. *Animal Production* 51, pp635-638

Pearson, R.A. and Holloway, P. (2000). A financial assessment of strategies to manage fasciolosis in goats in eastern Nepal. In: Mahato, S.N., Harrison, L.J.S. and Ghimire, S.C. (eds). *Proceedings of the workshop on Strategies for feed management in areas endemic for Fascioliasis*, pp32-41

Pokharel, R.K. (2001). Indigenous technical knowledge (ITK) of people on fodder tree management. Nepal net

Pokharel, R.K. (2000). Indigenous forest management practices in some community forests of Nepal. Banko Janakari. A journal of forestry information for Nepal. 10 (1), pp 36-39

Poppi, DP., McLennan SR., Bediye S., de Vega A. and Zorilla-Rios J. (1997). Forage quality: strategies for increasing nutritive value of forages. In: proceedings XVIII International grassland congress (in press).

Rangnekar, D.V. (1991). Farmer and scientist perceptions. Paper presented at international workshop on feeding of ruminants on fibrous crop residues. National Dairy Research Institute, Karnal, India.

Poudal, G.R., Nepali, D.B. and Singh, D.B. (1994). A comparative study of tree fodders and maize silage supplementation on growth performance of buffalo heifers. *Veterinary Review*, Kathmandu, Nepal, 9(1)

Poudel, K.C. (1997). Fodder biomass production from Badahar (*Artocarpus lakoocha*). *Veterinary Review*, 12(1), pp25-27

Poudel, K.C. and Rasali, D.P. (1996). Fodder biomass production from Badahar (*Artocarpus lakoocha*) and effect of its feeding on lactating buffalo. Paper presented at the National Livestock and Fisheries Research Workshop held at NARC, Khumaltar, Lalitpur, May 7-9

Poudel, K.C. and Rasali, D.P. (1996). Response of Badahar (*Artocarpus lakoocha*) feeding on lactating buffalo in the western hills of Nepal. LARC Working paper No: 96/44, Pokhara, Nepal

Poudyal, S.P. (2001). Economics of milk production on the high value crop-based farming systems: a case study of Ilam district, In: Singh, S.B., Aryal, I.K. and Rai, A.K. (eds). *Proceedings of the 4th National Animal Science Convention.* Nepal Animal Science Association (NASA), Kathmandu, Nepal

Pradhan, S.L. (1986), Small ruminant production systems in South and south East Asia. *Proceedings of workshop organized by international research centre and the small ruminants collaborative research support program,* Bogor, Indonesia, pp146-174

Provenza, F.D. (1995). Post-ingestive feedback as an elementary determinant of food selection and intake in ruminants. *Journal of Range Management*, 48, pp 213-220

Provenza, F.D.; Lynch, J.J., Burritt, E.A. and Scott, C.B. (1994). How goats learn to distinguish between novel foods that differ in post-ingestive consequences. *Journal of Chemical Ecology*, New York, 20(3), pp609-624

Rai, N.K. and Thapa, M.B. (1993). Indigenous pasture management systems in high-altitude Nepal: a review. Research report series, No 22, HMG/Winrock International, Policy analysis in agriculture and related resources management, Kathmandu, Nepal.

Rajbhandari, H.B. and Pradhan, S.L. (1991). Livestock development and pasture management. Background papers to the national conservation strategy for Nepal. 1, pp299-331

Rana, R.S., Amatya, N., Jalan, R. and Jha, P.K. (2000). Response of lactating buffaloes when fed with treated or untreated rice straw with Badahar (*Artocarpus lakoocha)* supplementation. In: Singh, S.B., Aryal, I.K. and Rai, A.K. (eds), *Proceedings of the 4th National Animal Science Convention*, NASA, Kathmandu, Nepal

Rangnekar, D.V. (1991). Farmer and scientist perceptions. *Paper presented at international workshop on feeding of ruminants on fibrous crop residues*. National Dairy Research Institute, Karnal, India.

Ranjhan, S.K. (1998). *Nutrient Requirement For Livestock And Poultry*. Indian council of Agricultural Research (ICAR), New Delhi, India

Rasali, D.P., Gurung, D.B., Gautam and Achhami, K. (1997). Livestock herds and their breeding management systems in the western hills of Nepal: an analysis through samuhik bhraman, *Proceedings of 2nd National Workshop on Livestock and Fisheries Research,* NASRI, NARC, Khumaltar, Lalitpur

Raut, Y., Pradhan, D.R. and Ranjit, A.S. (2000). Pasture development situation and its constraints for livestock production in Nepal. In: Sherchand, L, Pradhan, B.R, Bhurtel, R and Neopane, S. (eds.). *Environmentally sustainable livestock production for poverty alleviation*, Nepal Animal Science Association, Kathmandu, Nepal August 27-28

Reed, J.D. (1986). Relationships among phenolics, insoluble proanthocyanidins and fibre in East African browse species, *J. Range Manage* 39:5-7

Riley, K.W. (1991). Soil fertility maintenance for sustainable crop production in Soil fertlity and erosion in the middle mountains of Nepal. Workshop proceedings Kathmandu: HMG Topographical survey/University of British Columbia.

Rios, S., Correal, E and Robledo, A (1989). Palatability of the main fodder and pasture species present in S.E. Spain. II. Herbaceous species. Proceedings of XVth International Grassland Congress, Nice, 4-11 October, pp1533-1534

Robinson, P.J. and Thompson, I.S. (1989). Research needs in fodder trees. In: In: Yazman, J.A. and Oli, K.P. (eds). Proceedings of a workshop on research on research needs in livestock production and animal health in Nepal, pp 70-85. HMG/MA/NARSC/ARPP, Kathmandu

Roder, W. (1992). Experience with tree fodders in temperate regions of Bhutan. Agroforestry systems: 17, pp263-270

Roothaert, R.L. and Franzel, S. (2001). Farmers' preferences and use of local fodder trees and shrubs in Kenya. *Agroforestry Systems*. 52, pp239-252

Rusten, E.P. (1989). An investigation of an indigenous knowledge system and management practices of tree fodder resources in the middle hills of central Nepal. Unpublished PhD Thesis, Michigan state university.

Salem, H.M., Nefzaoui, H. and Abdouli, H. (1994). Palatability of shrubs and fodder trees measured on sheep and dromedaries: 1. Methodological approach, Animal Feed Science And Technology 46, pp143-153

Savory, R., Breen, J.A. and Beale, C.I.A. (1980). Leucaena as a forge crop on small farms in Malawi. In: Browse in Africa the current state of knowledge. ILCA, Addis Ababa, Ethiopia, pp411-414

Sawhney, P.C., Bedi, S.P.S., Khan, S.A. (1977). Note on trace element contents in the fodders of Jammu and Kashmir State. *Indian Journal of Animal Sciences*, 55, pp459-463.

Schoonmaker Freudenberger, K. (1994). Challenges in the collection and use of information on livelihood strategies and natural resource management. In: Scoones, I and Thompson (eds), Beyond farmer first: rural people's knowledge, *Agricultural Research And Extension Practice*, pp124-133

Schroeder, R.F. (1985). Himalayan subsistence systems indigenous agriculture in rural Nepal, *Mountain Research And Development*, 5(1), pp31-44

Scoones, I. and Thompson, J. (1994). Knowledge, power and agriculture-towards a theoretical understanding In: Scoones, I and Thompson (eds), *Beyond farmer first: rural people's knowledge, agricultural research and extension practice*, pp16-32

Sengar, S.S. and Naik, P.K. (1996). The complete feeding system for livestock. Pashudhan, volume 11 (8), Bangalore, India

Sharma, A.R. and Wagle, U.P. (1991). Livestock population in PAC outreach sites in the Mechi hills. *Veterinary Review*, 6, pp17-19, Kathmandu, Nepal

Sharma, L.P. (1985). Study on productivity of fodder tree. *Nepalese Journal of Animal Science*, 1(1), pp19-24

Sharma, VB., Sagar, V and Gupta, PC (1988). Prediction of nutritive value of tropical forages from chemical composition. *Indian Journal of Animal Sciences*, 58 (11): 1307-1314.

Sharma, L.P. and Pradhan, D.R. (1985). Present fodder resources and prospects for their development in the hills of Nepal. In: Morel, A.M. and Oli, K.P. (eds). *Livestock in the hills of Nepal*, Proceedings of the first livestock workshop held at Pakhribas Agricultural Centre, 5-7th Feb

Sherchan, D.P., Pilbeam, C.J. and Gregory, P.J. (1999). Response of wheat-rice and maize-millet systems to fertilizer and manure application in the mid-hills of Nepal. *Experimental Agriculture.* 35, pp1-13

Shrestha, K.M. (2000). Strategies for Coping with Fodder Deficits in Makwanpur District, Central Nepal. Seasonal patterns of livestock feed collection and deficits on small-holder mixed farms in the mid-hills zone of Nepal. *Proceedings of the National Workshop on Improved Strategies for Identifying and Addressing Fodder Deficits in the Mid-hills of Nepal,* 5-6 September

Shrestha, N.P. (1992). Potential and prospects of straw feeding in ruminant production systems in the eastern hills of Nepal. In: Romney, D.L., Orskov, E.R and Gill, M. (eds). *Workshop proceedings of the utilisation of straw in ruminant production systems.* 7-11 October, Malayasian Agriculture Research and Development Institute (MARDI), Malayasia pp87-100

Shrestha, N.P. (1993). Monitoring of the productivity and production systems of animals at high altitude pastures, PAC Working Paper N0: 74, Pakhribas Agricultural Centre, Dhankuta, Nepal.

Shrestha, N.P. and Pakhrin, B. (1989), Effect of different tree fodders on milk production in buffaloes, PAC Technical paper 117, Pakhribas Agricultural Centre, Kathmandu, Nepal

Shrestha, N.P., Oli, K.P. and Gatenby, R.M. (1989). Milk production of local and Murrah crossbred buffaloes and local and Jersey crossbred cows in the hills of East Nepal. Technical Paper 97, Pakhribas Agricultural Centre, Dhankuta, Nepal.

Shrestha, S.R. and Mahato, R.C. (1992). Oat cultivation as a winter fodder in Ilam district. Veterinary Review, Pakhribas Agricultural Centre, Kathmandu, Nepal

Shrestha, T.P. (1983). Economic contribution by livestock farming. *Bulletin of Veterinary Science And Animal Husbandry.* Nepal, 12, p.2

Silanikove, N., Gilboa, N., Perevolotsky, A and Nitsan, Z (1996). Goats fed tannin-containing leaves do not exhibit toxic syndromes. *Small Ruminant Research* 21, pp195-201

Sinclair, F.L. and Walker, D.H (1998). Acquiring qualitative knowledge about complex agroecosystems. Part 1; Representation as natural language. Agricultural Systems, Vol 56, No. 3, pp 341-363

Singh, N.B., Karki, N.P.S. and Shah, B.K.P. (2000). Status of livestock production in Nepal. Environment and Agriculture: at the cross road of the new millennium, *Proceedings of the international conference on environment and agriculture,* Kathmandu

Singh, S.B. (2000). Leasehold forestry and forage development project: innovative livestock and forage training and extension strategies. In: Singh, S.B., Aryal, I.K. and

Rai, A.K. (eds). *Proceedings of the 4th National Animal Science Convention*, Nepal Animal Science Association (NASA), Kathmandu, Nepal

Singh, S.B. (2001). Strategies and alternative approaches for future growth of the livestock sector in Nepal. In: Sherchand, L., Pradhan, B.R., Bhurtel, R. and Neopane, S.P. (eds). Proceeding of the conference *Environmentally sustainable livestock production for poverty alleviation.* Nepal Animal Sciences Association, Nepal (NASA), Lalitpur, Nepal

Singh, K.A. (1998). Nutrient contents in the important fodder trees of eastern Himalayan as influenced by leaf position and month of lopping. Journal of Hill Research, 11(1), 1-7. Sikkim Science Society, India

Sthapit, B.R. (1990). Comparative performance of indigenous green manuring species on yields of rice. *Journal of Institute of Agriculture and Animal Science,* Rampur, 11:9-14

Subba, D.B. (1998). Chemical composition and nutritive values of feeds of east Nepal, Pakhribas Agricultural Centre, Dhankuta, Nepal.

Subba, D.B. and Tamang, P.M. (1990). Seasonal variation in the chemical composition of the leaves of ficus spp fodder trees. In: Proceedings of the third meeting of the working group in fodder trees, forest fodder and leaf litter. FRIC, Kathmandu, Nepal. Occasional paper, No 2/90, 20-24, Kathmandu, Nepal

Subba, D.B. (1999). Tree fodders & browse plants as potential nutrient suppliers for ruminants. In: Neopane, S.P. and Khanal, R.C. (eds). Third livestock and fisheries workshop, Agricultural Research Centre, Lumle 12 –14, Kathmandu, Nepal, pp1-14

Subba, D.B. (2001). Tannin in tree fodders and browse plants in the eastern hills of Nepal. Proceeding of the conference of Nepal Animal Sciences Association, Nepal (NASA), Lalitpur, Nepal

Subba, D.B. (2002). *Local Knowledge on Tree Fodders And Its Biological Equivalence In Simple Terms. A Booklet For Farmers (in Nepali*). Agricultural Research Station, Pakhribas, Dhankuta, Nepal

Subba, D.B. and Singh, S.K. (2001). Bamboo as important feed for ruminants in the Eastern hills of Nepal. Proceedings of the 4th livestock and fisheries workshop, Agricultural Research Centre, Pakhribas, 12 –14 Baisakh 057, Kathmandu, Nepal

Subba, D.B. and Tamang, P.M. (1990). Tannin in tree fodders in Dhankuta district of east Nepal, *Veterinary Review*, Pakhribas Agricultural Centre, and Dhankuta, Nepal.

Subba, D.B. and Tamang, P.M. (1993). Notes on deleterious plants of eastern hills of Nepal. *Veterinary Review*, 8 (1), pp4-10 Kathmandu, Nepal

Subba, D.B., Gurung, H.B. and Tamang, B.B. (1996). Seasonality of polyphenolics in nine important tree fodders in the eastern hills of Nepal. *Veterinary Review*, 11(1), pp8-10, Pakhribas Agricultural Centre, Dhankuta, Nepal.

Subba, D.B., Mahato, S.N., Harrison, L.J.S. and Pearson, R.A. (2000). The interaction between *Fasciola gigantica* infection and nutrition in growing Nepalese hill buffaloes. In: Mahato, S.N., Harrison, L.J.S. and Ghimire, S.C. (eds). *Proceedings of the workshop on Strategies for feed management in areas endemic for Fascioliasis*, pp 32-41

Subba, D.B., Tamang, B.B. and Tamang, P.M. (1992). Availability of protein from high altitude tree fodders in the hills of east Nepal. *Veterinary Review*, 7 (2), pp55-57, Kathmandu, Nepal

Subba, D.B. (2002). Local Knowledge on Tree Fodders And Its Biological Equivalence In Simple Terms. A Booklet For Farmers (*in Nepali*). Agricultural Research Station, Pakhribas, Dhankuta, Nepal

Subedi, K.D. (1997) Indigenous green manure in Nepal. *LEISA Newsletter* 13 93, pp16-17

Thakuri, K.C., Mahato, S.N. and Thakur, R.P. (1992). Diseases of cattle and buffalo in the Koshi hills of Nepal: a retrospective study. *Veterinary Review*, Kathmandu, Nepal

Thapa, B. (1985). Fodder production - experience of Pakhribas Agricultural Centre (PAC). In: Morel, A.M. and Oli, K.P. (eds). *Livestock in the hills of Nepal*, Proceedings of the first livestock workshop held at Pakhribas Agricultural Centre, 5-7th Feb

Thapa, B. (1994) *Farmers' ecological knowledge about the management and use of farmland tree fodder resources in the mid-hills of eastern hills of Nepal.* PhD Thesis, University of Wales, Bangor

Thapa, B., Joshi, L. and Sherpa, S.L. (1989). Traditional agriculture and resource use under pressure: scope for agro-forestry intervention in the middle hills of Nepal. PAC Occasional paper, Pakhribas Agricultural Centre, Kathmandu, Nepal

Thapa, B., Joshi, L. and Sherpa, S.L. (1990). Fodder research and development activities at PAC. In: Amatya, S.M. and Philip, M.S. (eds). *Proceedings of the third meeting of the working group on fodder trees, forest fodder and leaf litter.* FRIC Occasional paper No: 2/90, Forest Research and Information Centre, Kathmandu Nepal, pp4-10.

Thapa, B., Walker, D.H., Sinclair, F.L., (1997) Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science and Technology,* 67, pp97 - 114.

Thorne, P.J. and Tanner, J.C. (2002). Livestock and nutrient cycling in crop-animal systems in Asia. *Agricultural Systems*. 7, pp111-126.

Thorne, P.J., Sinclair, F.L. and Walker, D.H. (1997). Using local knowledge of the feeding value of tree fodder to predict the outcomes of different supplementation strategies. *Agroforestry Forum*, 8 (2), pp45 - 49.

Thorne, P.J., Subba, D.B., Walker, D.H., Thapa, B., Wood, C.D. and Sinclair, F.L. (1999). The basis of indigenous knowledge of tree fodder quality and its implications for improving the use of tree fodder in developing countries. *Animal Feed Science and Technology,* 81, pp119-131.

Thorne, P.J., Tanner, J.C. and Gurung, H.B. (1998). The characterization of feed resources in crop-livestock systems and its implications for the development of improved feeding strategies- a case study from Nepal. *Agricultural Systems*

Thorne, P.J., Walker, D.H., Subba, D.B., Wood, C.D., Sinclair. F.L. and Thapa, B. (1997). Predicting the nutritive value of tree fodder: consistency and complementarity between assessments made by Nepalese smallholder farmers and by laboratory techniques. Proceedings of the British Society of Animal Science, p 201.

Thorne. P.J., Walker, D.H., Subba, D.B. and Sinclair, F.L. (2000). Combining farmers' knowledge about tree fodder with science in the eastern mid hills of Nepal. *Proceedings of the National level workshop on: Improved strategies for identifying and addressing fodder deficits in the mid-hills of Nepal.* pp73-79, DFRS/NRI, Kathmandu, Nepal

Tolera, Adugna., Khazaal, K. and Ørskov, E.R. (1997). Nutritive evaluation of some browse species. *Animal Feed Science And Technology*, 67, pp181-195

Undersander, D., Mertens, D.R. and Thiex, N. (1993). National forage testing association recommended analyses procedures. USA

Upadhyaya, R.M. (1991). Future steps for development of livestock industry of Nepal. In: Panday, S.B., Joshi, N.P., Adhikari, B.R. and Upreti, C.P. (eds), *Animal Science Research, Production And Extension In Nepal.* Proceedings of the first national animal science convention, Jan 14-15, Lalitpur

Upton, P. (1990). Effects of altitude, aspect and season on the use of fodder trees species in south Lalitpur district. Banko Janakari, 2 (3)

Van Soest, P.J. (1994). Nutritional ecology of the ruminant, 2nd edition, Cornell University press, Ithaca, NY

Van Soest, P.J. and Robertson, J.B. (1985). *Analysis of forages and fibrous foods. A Laboratory Manual For Animal Science*, 613 Cornell University, USA.

Van Soest, PJ (1981). Limiting factors in plant residues of low bio-degradability. *Agriculture Environment*. 6:135-143

Van Soest, PJ (1983). Nutritional Ecology of The Ruminant. Cornell University, USA
Walker, D.H. and Sinclair, F.L. (1998). Acquiring qualitative knowledge about complex agro-ecosystems. Part 2: Formal Representation. *Agricultural Systems*, 56 (3), pp 365-386

Vabi, M. (1996). Eliciting community knowledge about uses of trees through participatory rural appraisal methods: example from Cameroon and the Central African Republic. Rural Development Forestry Network Paper 19e, Overseas Development Institute, London

Walker, D.H. and Sinclair, F.L. (1998). Acquiring qualitative knowledge about complex Agroecosystems. Part 2: Formal representation, Agricultural Systems, Vol 56, No. 3, pp 365-386

Walker, D.H., Sinclair, F.L., Joshi, L. and Ambrose, B. (1997). Prospects for the use of corporate knowledge bases in the generation, management and communication of knowledge at a frontline agricultural research centre. 54(3) pp291-312

Walker, D.H., Thorne, P.J., Sinclair, F.L., Thapa, B., Wood, C.D. and Subba, D.B. (1999). A system approach to comparing indigenous and scientific knowledge: consistency and discriminatory power of indigenous and laboratory assessment of the nutritive value of tree fodder. Agricultural systems 62:87-103

Walker, D.H., Sinclair, F.L and Kendon, G. (1995), A knowledge-based systems approach to Agro-forestry research and extension, *AI Applications*, 9(3), pp61-72

Wanapat, M. (1985) Improving rice quality as ruminant feed in Thailand. Proceedings of the International Workshop on Relevance of Crop Residues as animal feeds in developing countries. M Wanapat and C. Devendra (eds), Funny press, Bangkok, Thailand

Warren, D.M. (1991). Using indigenous knowledge in agricultural development, World Bank Discussion Paper No 127, The World Bank, Washington, D.C.

Warren, D.M. and Cashman, K. (1988). Indigenous knowledge for sustainable agriculture and rural development. Gatekeeper series no SA10, sustainable agriculture programme, International institute for environment and development, Centre for arid zone studies

Wattiaux, M.A. (1995). Dairy enterprise support component of agro enterprise technology systems project, Dairy Enterprises Support Component, Chemonics International Consulting Division, Washington DC, USA

Wood, C.D., Tiwari, B.N., Plumb, V.E., Powell, C.J., Roberts, B.T., Padmini sirimane, V.D., Rossiter, J.T. and Gill, M. (1994). Interspecies differences and variability with time of protein precipitation activity of extractable tannins, crude protein, ash, and drymatter content of leaves from 13 species of Nepalese fodder trees. *Journal of Chemical Ecology*. 20(12), pp3149-3162

Yadav, B.D. (1992). An assessment of farmer's knowledge of fodder in Jumla, In: *Proceeding of forth meeting of the working group on fodder tree, forest fodder and leaf litter*. Forest Research Division, Kathmandu, Nepal, Occasional Paper 1/92. pp26-30

Yazman, J. (1987). Memorandum on body weight predictor equations. Agriculture research and production project, Ministry of Agriculture, Kathmandu, Nepal

Zerbini, E. and Wold, A. G. (1999). Feeding dairy cows for draught. In: Falvery, L and Chantalakhana, P. (eds). *Small holder dairying in the tro*pics, International Livestock Research Institute, Kenya

Appendix 2.1 Feeds and fodder resources, animals and their productivity in the households of study sites

Date surveyed:...

Farmer's name:...**village**...................................**District:** ....

1. How many lactating animals did you have 2 years ago ? A. Cow nos. B. Buffalo nos

What was the yield of milk and ghee last year ?
A. Milk B. Ghee

2. How many lactating animals did you have last year ? A. Cow nos. B. Buffalo nos

What was the yield of milk and ghee last year ?
A. Milk B. Ghee

3. Animal species, numbers and types owned

Animal species	Breed	Numbers	Animal species	Breed	Numbers
Milch Animals			Meat animals		
Cows			Male Buffalo		
Buffalo			Goats		
Draft animals			Sheep		

4. What is the average productivity of milk or ghee of your animals per parity ?

Animal spp.	Breed	Milk yield (litre)	Ghee (Kg)
Cow			
Buffalo			

5. What was your income from the sale of animals or meat last year ?

Animal spp.	Animal or meat sale (Rs.)	Amount (Rs.)	Animal spp.	Animal or meat sale	Amount (Rs.)
Goats			Buff		
Sheep			Oxen		
Calves			Others		

6. What are the different types of land you own (in *ropani*) ?.

A. *Khetland* B. *Bariland* C. Forest D. Wasteland

7. Where and how much fodder do you collect annually?

Fodder type	Collected from	Amount collected (Kg/*bhari*)	Fodder type	Collected from	Amount collected (Kg/*bhari*)
Dry fodder	*Khet* land		Fodder trees	*Khet* land	
	Bari land			*Bari* land	
	Forest			Forest	
	Wasteland			Wasteland	
Forages	*Khet* land		Others	*Khet* land	
	Bari land			*Bari* land	
	Forest			Forest	
	Waste land			Waste land	

8. How do you supply different feed types to your lactating animals each month?

Month	Forage	Tree fodder	Dry fodder	Concentrate
Falgun				
Chaitra				
Baisakh				
Jestha				
Asar				
Shrawan				
Bhadra				
Asoj				
Kartik				
Mangsir				
Poush				
Magh				

9. How are you keeping your animals?

A. Cow/female buff ☐ Stalled ☐ semi-intensive ☐ Grazing

B. Ox/male/ male buff ☐ Stalled ☐ semi-intensive ☐ Grazing

C. Sheep/goats ☐ Stalled ☐ semi-intensive ☐ Grazing

10. How many days animals go for grazing and the estimated amount of fodder they receive from grazing annually?

Animal species	Grazing hrs (day)	Amount of fodder received from grazing (annual)
Cow/buff		
Ox/buff		
Sheep/goats		

11. What is the amount of feed types you obtain from your land?

Feed type		Average amount of feed type (kg/*bhari*)
Dry fodder	1. Rice straw	
	2. Maize stover	
	3. Millet straw	
	4. Maize sheath	
	5. Others	
Improve grass	1.	
	2.	
	3.	
Tree fodder	1.	
	2.	
	3.	
	4.	
Oilseeds & grain	1. Compound feed 2. Maize flour 3. Wheat bran 4. Rice bran 5. Oilseed cake 6. Others	
Grass	Mixed grass	

12. Do you prepare concentrate at home to feed your animals?

A. Yes ☐ B. No ☐

13. If yes, how do you formulate a homemade concentrate and where do you get them?

Ingredients mixed	Weight	%	Cost.kg^{-1}	Approx cost
Total		100		

14. What is the composition of a *Khole* by season ?

Month	Ingredient for *khole*	Mixed amount (kg)	Month	Ingredient for *khole*	Mixed amount (kg)
Baisakh			*Kartik*		
Jestha			*Mangsir*		
Asar			*Poush*		
Shrawan			*Magh*		
Bhadra			*Falgun*		
Asoj			*Chaitra*		

15. Do you feed concentrate to all animals or only to lactating animals?

A. To all animals ☐ ☐ B. To lactating animals only

16. Will you feed concentrate from pre-partum period or only after parturition?

A. from pre-partum ☐ B. After parturition ☐ C. All any time ☐

17. Will you feed concentrate from pre-partum period or only after parturition?

18. Is exotic breeding bulls are available to cross your animals?

A. Available ☐ B. Not available ☐

19. What are the various dry fodders do you acquire?

1.

2.

3.

20. What are the various green forage types you acquire?

1.

2.

3.

21. Is the dry fodder enough for feeding to your animals?

1. Adequate 2. Inadequate 3. Surplus

22. If the rice straw is inadequate do you purchase them?

1. Buy 2. Do not buy

23. If you buy, what is the quantity of rice straw you purchase by season?

Month	Quantity purchase	Cost (Rs.)/ *bhari*	Month	Quantity purchase	Cost (Rs.)/ *bhari*
Baisakh			*Kartik*		
Jestha			*Mangsir*		
Asar			*Poush*		
Shrawan			*Magh*		
Bhadra			*Falgun*		
Asoj			*Chaitra*		

24. Is the green fodder enough for feeding to your animals?

1. Adequate 2. Inadequate 3. Surplus

25. If the green fodder is inadequate do you purchase them?

1. Buy 2. Do not buy

26. If you buy, what is the quantity of green fodder you purchase by season?

Month	Quantity purchase	Cost (Rs). *bhari*$^{-1}$	Month	Quantity purchase	Cost (Rs.) *bhari*$^{-1}$
Baisakh			*Kartik*		
Jestha			*Mangsir*		
Asar			*Poush*		
Shrawan			*Magh*		
Bhadra			*Falgun*		
Asoj			*Chaitra*		

Appendix 2.2 Records of feed intake and details of monitored animals

Date surveyed: --------------------------------

Farmer's name: ------------------Village--------------------------District: --------------------------------

Details of animals monitored:

Animal species	Exotic	Cross	Local	Total	Weight	Body condition score (1-5 scale)	Milk yield per lactation (kg)	Remark
1.								
2.								
3.								
4.								

Records of feed intake by monitored animals:

Animal type	Feed type offered in the morning		*khole* type fed in the morning		Grazing hours (time/hrs)		
	Offered	Left over	Offered	Left over	From	To	Approx. intake (kg)

Note: Collect feed samples for lab analysis at Pakhribas

Surveyor's name.....................Date.............................

Appendix 2.3 List of tree fodder based on their abundance (%) (pooled data of overall sites)

Tree species.	*Latin name*	%
Dudhilo	*Ficus nerrifolia var nemoralis*	20.37
Bans	*Bamboo spp*	11.21
Painyu	*Prunus cerasoides*	10.43
Nebharo	*F auriculata*	7.38
Khasre khanyu	*F. semicordata var semicordata*	6.94
Gogun	*Saurauia nepaulensis*	6.06
Chamlayo	*Symplocus robusta*	4.94
Rato siris	*Albizia chilensis*	4.87
Amliso	*Thysanolaena maxima*	4.14
Kutmiro	*Litsea monopotela*	3.57
Tanki	*Bauhinia purpurea*	3.21
Rai khanyu	*F. semicordata var montana*	2.30
Bhimsenpati	*Budleja asiatica*	2.05
Chuletro	*Brassiopsis glomerulata*	1.57
Bilaune	*Maesia chisia*	1.55
Ghurbish	*Lecucoseptrum canum*	1.46
Jhingani	*Eurya cerasifolia*	1.34
Timbur	*Zanthoxylum armatum*	1.24
Kabro	*F lacor*	0.88
Ghotli	*Sambucus hookeri*	0.84
Kimbu	*Morus alba*	0.68
Koiralo	*Bauhinia variegate*	0.68
Badahar	*Artocarpus lakoocha*	0.50
Kunyel	*Grewia trema-orientalis*	0.35
Bar	*Ficus bengalensis*	0.34
Lute khanyu	*Ficus spp*	0.34
Khari	*Celtis aurtralis*	0.15
Thotne	*F. hispida*	0.14
Lati kath	*Cornus oblanbga*	0.11
Syal fusro	*Grewia tiliaefolia*	0.10
Gayo	*Bridelia retusa*	0.08
Kangiyo	*Wendlandia exserta*	0.08
Bohari	*Cordia dichotonoma*	0.05
Kaulo	*Machilus odoratissima*	0.04

Appendix 2.4 Leaf biomass yield from various farmland fodder tree species (estimated amount in $kg.tree^{-1}year^{-1}$) (pooled data of overall sites)

Tree species (N)	*Latin name*	Kg per tree (range)
Ghotli (16)	*Sambucus hookeri*	249.0 (2-2450)
Kunyel (5)	*Grewia trema-orientalis*	224.0 (70.0-525)
Badahar (20)	*Artocarpus lakoocha*	179.1 (29.2-875)
Rai khanyu (53)	*F. semicordata var montana*	168.6 (2.9-700)
Koiralo (5)	*Bauhinia variegate*	168.0 (35-350)
Kabro (25)	*F lacor*	142.1 (2.9-525)
Kathe bar (2)	*Ficus bengalensis*	122.5 (70-175)
Lute khanyu (9)	*Ficus spp*	107.9 (14.0-210)
Tanki (87)	*Bauhinia purpurea*	83.0 (1.8-875)
Khari (4)	*Celtis aurtralis*	72.2 (8.8-175)
Gayo (2)	*Bridelia retusa*	61.3 (17.5-105)
Khasre khanyu (147)	*F. semicordata var semicordata*	59.7 (0.83-525)
Nebharo (171)	*F auriculata*	55.8 (0.51-700)
Kangiyo (2)	*Wendlandia exserta*	52.5 (35-70)
Lati kath (4)	*Cornus oblanbga*	50.3 (8.8-140)
Gogun (146)	*Saurauia nepaulensis*	46.5 (0.73-525)
Chuletro (34)	*Brassiopsis glomerulata*	42.6 (3.50-140)
Dudhilo (577)	*Ficus nerrifolia var nemoralis*	38.3 (0.50-700)
Rato siris (204)	*Albizia chilensis*	36.4 (0.51-560)
Kimbu (32)	*Morus alba*	35.8 (1.8-350)
Timbur (26)	*Zanthoxylum armatum*	34.0 (3.5-245)
Painyu (399)	*Prunus cerasoides*	32.0 (0.51-700)
Kutmiro (149)	*Litsea monopotela*	31.3 (0.50-350)
Thotne (5)	*F. hispida*	29.8 (8.8-70)
Syal fusro (2)	*Grewia tiliaefolia*	26.2 (17.5-35)
Jhingani (28)	*Eurya cerasifolia*	25.1 (4.38-70)
Chamlayo (234)	*Symplocus robusta*	18.6 (0.51-350)
Ghurbish (57)	*Lecucoseptrum canum*	18.5 (1.35-175)
Bilaune (38)	*Maesia chisia*	16.8 (1.75-105)
Bhimsenpati (113)	*Budleja asiatica*	8.6 (0.51-70)

Appendix 2.5 List of 33 different grasses available during the wet season

Local name	Latin name
Abhijalo	*Drymaria diandra*
Armale	*Aeschynomine indica*
Banso	*Eragrostic tennella*
Banspate	*Latin name unknown*
Chiple	*Villebrunnea frutescens*
Dhotisaro	*Latin name unknown*
Dhungreful	*Latin name unknown*
Dhus	*Latin name unknown*
Dubo	*Cynodon dactylon*
Fuljhar	*Latin name unknown*
Furke	*Arunduella nepalensis*
Gagleto	*Latin name unknown*
Halhale	*Elephantopus scaber*
Ilame	*Lindenbergia indica*
Kane	*Latin name unknown*
Kans	*Vetiverra zizanioides*
Karoute	*Latin name unknown*
Kharuki	*Pogonatherum incans*
Kuro	*Cynodon dactylon*
Lekalihade	*Latin name unknown*
Lipe	*Latin name unknown*
Mothe	*Cyperus rotundus*
Napier	*Pennisetum purpureum*
Narkat	*Arundo clonax*
Niguro	*Latin name unknown*
Ratneulo	*Persicaria hydropiper polygonacae*
Rimai	*Latin name unknown*
Salimbo	*Chrysopogon gryllus*
Sanma	*Latin name unknown*
Setaria	*Setaria anceps*
Siru	*Imperata cylindrical*
Udase	*Latin name unknown*
Unieu	Fern *spp.*

Appendix 3.1. Feeding and management of tree fodders

Name of farmer: ....

Address: ....

Age:..

Wealth status: ....

Date of interview: ....

Date surveyed: --------------------------

Farmers' name: -------------------------- village--------------------------District: ---------------
----

1. Name the various species of trees that are available for feeding during the dry season.

Tree species	Available for feeding		
	Chaitra	Baisakh	Jestha

2. What are the leaf flushing months, right feeding season and lopping season of the tree species available in your farmland?

Tree species	Flushing month	Feeding/lopping month	Flushing month (next year)	Feeding/lopping month (next year)

3. What do you understand by Posilopan, Obhanopan and Adilopan of tree fodders ?

4. Will *posilo*, *adilo* and *obhano* characteristics of a tree leaves be determined by observing dung/urine, animal health/productivity, colour, texture and thickness of leaves? If yes, how can they be identified and what is the impact of feeding a *posilo*, *adilo* and *obhano* type of tree leaves?

5. Do you mix *posilo/kamposilo*, *adilo/kamadilo*, *chiso/obhano* characteristics of different tree leaves to feed to your animals? What are the reasons for feeding by mixing and without mixing?

6. Will the obhano and chiso characteristics of a tree change with weather condition? If yes, which tree species, how and when do they change?

7. Will the Posilo and Kamposilo characteristics of a tree change with weather condition? If yes, which tree species, how and when do they change?

8. Farmers decision for feeding Obhano, Posilo and Adilo tree fodders i.e. which tree species are preferably fed to which type of tree species?

Animal type	Obhano	Posilo	Adilo
1. Lactating cows			
2. Draught animals			
3. Calves			

What are the reasons for feeding *Obhano* tree fodders to lactating cows or draught animals or calves?

What are the reasons for feeding Posilo tree fodders lactating cows or draught animals or calves?

What are the reasons for feeding Adilo lactating cows or draught animals or calves?

Appendix 3.2. Local strategies for feeding management during the dry season.

Name of farmer: ....

Address: ....

Age:..

Wealth status: ....

Date of interview..

1. Local strategies for feeding management during the dry season

Uses of dry roughages during the dry season.

Do you conserve rice straw or maize stovers for dry season feeding? (Yes/No)

Do you purchase rice straw or maize stovers for dry season feeding? (Yes/No)

Do you conserve dried grasses for dry season feeding? (Yes/No)

Other practice/s

Utilization of low palatable fodders.

Do increase in supply of low palatable or unpalatable fodder in small amount? (Yes/No)

Do you supply low palatable fodders in the evening or night? (Yes/No)

Other practice/s ....

Management of animals during the dry season

Do you sale dry cattle or buffalo at or before the dry season approaches? (Yes/No)

Do you mobilise animals to your neighbours for their feeding in exchange of manure? (Yes/No)

Do local purchase young animals to replace large animals? (Yes/No)

Other practice/s ....

Manipulation of calving time

Do you manipulate breeding of animals to correspond with the abundance of wet season grasses? (Yes/No)

Other practice/s ....

2. What is the effect of sunshine, wind and soil moisture on leaf fall, fodder quality, fodder productivity and shelf life of tree?

Parameter	Sunshine		Windy		Soil moisture content		
	Shaded	Sunny	Low wind	High wind	More water content	Low water content	Dry land
Leaf fall (high or low)							
Fodder quality (posilo or kam-posilo)							
Fodder productivity (high or low)							
Life span of tree (long or short)							

3. Please indicate which of these species are *kharo, kafalo* and *pocho* in terms of fuel value?

kharopan: Intense heat and slow burning class of firewood (desirable)

kafalopan: Firewood characterised by fast burning with poor heat (undesirable)

pochopan: Firewood characterised by difficult to burning (undesirable)

Tree species	*Kharopan*	*Kafalopan*	*Pochopan*
Amliso			
Badahar			
Bhimsenpati			
Chuletro			
Dudhilo			
Gogun			
Kabro			
Khasre khanyu			
Malbans			
Nebharo			
Painyu			
Patmiro			
Rai khanyu			
Rato siris			
Tanki			

4. Please rank the following tree species for their manure properties based on *tikaupan*, Leaf decomposition rate, bulk density, solidness and ease to transport manure. Please give score 1 for desirable characteristics and 15 for undesirable characteristics.

Manure properties of tree fodders

Tree species	*tikaupan* of manure (*tikau/ kamtikau*)	Leaf decomposition (slow or fast)	Heaviness of manure (heavy or light)	Manure compactness (solid or loose)	Transportation (easy or difficult)
Amliso					
Badahar					
Bhimsenpati					
Chuletro					
Dudhilo					
Gogun					
Kabro					
Khasre khanyu					
Malbans					
Nebharo					
Painyu					
Patmiro					
Rai khanyu					
Rato siris					
Tanki					

5. Please rank the following tree species for their manure properties based on the parameters given. Please give score 1 for desirable characteristics and 15 for undesirable characteristics.

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Feeding quality															
Easy to lop/strong branch															
Fodder yield (less time required to collect)															
Easy to carry															
Tree age (long/short)															
Effect to crop															
Less prone to disease infection															
Manure quality (*tikaupan* or *kamtikaupan*)															
Fuel properties (*kharopan/pochopan/kafalopan*)															
Household use															
Easy to propagate															
Fast growing															
Longer retention of tree leaves															

1: Nebharo, 2: Dudhilo, 3: Gogun, 4: Khasre khanyu, 5: Rai khanyu, 6: Painyu, 7: Tanki, 8: Kabro, 9: Amliso, 10: Malbans, 11: Rato siris, 12: Patmiro, 13: Bhimsenpati, 14: Chuletro and 15: Badahar

Appendix 3.3 Synonyms of some tree species in the eastern and western middle hills of Nepal

Latin names	Eastern hills	Western hills*
Thysanolaena maxima	*Amliso*	*Amriso, olso or olso*
NA	*Badkiunle*	*Bella or bedula*
Buddleja asiatica	*Bhimsenpati*	*Phusherpate*
Symplocus robusta	*Chamlayo*	*Chamade or khadku*
Boehmeria regulosa	*Dar*	*Githi*
Ficus nemoralis	*Dudhilo*	*Dullo or dulla*
Grewia optiva	*Ghotli or Ghorli*	*Bhyaul or bhiul*
Celtis australis	*Khari*	*Khadku*
Ficus semicordata var semicordata	*Khasre khanyu*	*Khasre*
Morus alba	*Kimbu*	*Kimi*
Bauhinia variegata	*Koiralo*	*Koiral*
Bamboosa nutans	*Malbans*	*Bans**
Ficus auriculata	*Nebharo (nimaro)*	*Timlo or timali*
Ficus semicordata var Montana	*Rai khanyu*	*Khanyu or kanayo or khanim*
Bauhinia purpurea	*Tanki*	*Tanki or malpate*

Source: Angsingh Mehera, Baitadi district, Farwestern, Nepal; *only malbans is available in west Nepal

Appendix 3.4 Major reasons given by farmers for preference of tree fodders

Tree species	Reasons for preferring this species	Reasons for not-preferring this tree species
Malbans	1.Multiple household uses 2.Palatable and *posilo* to all animals 3.Promotes milk and butterfat yield 4.*Obhano* and *adilo*	1.Causes moderate shading effect 2.Roots expose on surface 3.Difficult to harvest fodder
Amliso	1.Flower is used for making brooms 2.Causes little shading effect 3.Multiple household uses 4.*Posilo* and promotes milk and butterfat 5.Longer retention of leaves	1.Poor fuel value (*pocho*) 2.Difficult to harvest (sharp leaf blades/tough skin) 3.Low fodder yield 4.Continuous feeding weakens animals
Badahar	1.Bears edible fruits 2.Posilo, promotes, milk and butterfat yield 3.Palatable to all animals 4.High timber value	1.Poor fuel value (*pocho*) 2.Causes higher shading effect 3.Difficult to harvest fodder (tall)
Nebharo	1.Yields more fodder 2.High fuel value (*kharo*) 3.Leaves have ceremonial uses 4.Palatable and *posilo* to all animals	1.Causes high shade and *tapkan* effect 2.Does not grow well on dry soil
Rai khanyu	1.Yields more fodder 2.High fuel value *(kharo)* 3.Palatable to all animals 4. *Adilo* and *obhano* 5.Longer retention of leaves	1.Causes high shade and *tapkan* effect 2.Mature leaves are unpalatable 3.Roots decrease soil fertility
Patmiro	1.Yields more fodder 2.Making leaf plates 3.Longer retention of leaves	1.Difficult to harvest fodder (branches are weak) 2.Mature leaves are unpalatable 3.Poor fuel value (*kafalo)* 4. Roots cause decrease in soil fertility
Bhimsenpati	1.Flower can be used for worship 2.Palatable to sheep & goats 3.Good fuel value	1.Kam-posilo and unpalatable to cattle & buffalo 2.Drops butterfat yield 3.Low fodder yield 4.Short life span of tree
Kabro	1.Shoots can be eaten as salad 2.High fuel value (*kharo*) 3.Yields more fodder 4.Easy to propagate 5.Promotes milk and butterfat yield	1.Causes moderate shading effect 2.Young leaves stick in the throat 3.Roots expose on the surface
Khasre khanyu	1.High fuel value (*kharo*) 2.Dry season fodder 3.*Obhano & adilo* fodder 4.High timber value	1.Drops milk yield 2.Mature leaves are unpalatable 3.Causes moderate shading & *tapkan* effect 4.Kamposilo
Dudhilo	1.High fuel value (*kharo*) 2.Palatable to all animals 3.Promotes milk yield 4.Palatable to all animals	1.Causes moderate shading effect 2.Young leaves cause throat sticking 3.*Kamposilo* and *kamadilo* to all animals
Rato siris	1. High timber value 2. *Obhano* and *posilo* to all animals 3. Leaves decompose quicky 4. Improves soil fertility 5. High fuel value	1.Young leaves are highly poisonous 2.Shorter retention of leaves 3.Yields low fodder 4.Difficult to harvest fodder (tall)
Tanki	1.Shoots can be eaten as salad or vegetable 2.Promotes milk and butterfat 3.Palatable and *adilo* to all animals 4.High fuel value (*kharo*)	1.Mature leaves are unpalatable 2.Susceptible to pest infestation
Painyu	1.Palatable and *Posilo* to sheep & goat 2.Higher timber value 3.Dry season fodder	1.Causes problem of *lahumute* (red urine) 2.Unpalatable and kam-posilo to cattle & buffalo
Gogun	1.Dry season fodder 2.High fodder yield 3.Bears edible fruits 4.Longer retention of leaves	1.Causes moderate shading effect 2.Poor fuel value (*kafalo)* 3.Chiso and not palatable during winter 4.Branches are weak and breakable
Chuletro	1.Palatable to all animals 2.Leaves decompose quickly and improves fertility of soil 3.Causes little shading effect 4.*Posilo* to sheep & goats	1.Poor fuel value (*pocho)* 2.Branches are weak and breakable 3.Difficult to harvest fodder (thorny) 4.Low fodder yield

Appendix 4.1 Daily intake of tree fodder by the cows

Farmers name: Address:

Animal type: Cows/buffalo:

Tree species examined:

Basal feed: Rice straw (local practice)

Amount of local concentrate to be fed:

Remark: Please do not feed other fodder and concentrates

Date	Tree fodder fed (kg)	Left over tree fodders/stakes (kg)	Intake of tree fodder (kg)

Appendix 4.2 Daily measurement of milk yield from the cows

Farmer's name:.........................Address.........................

Animal type:................Cow/buffalo.........................

Age ....Breed...................Parity...................

Date conceived.....................Date calved..................

Experimental tree species:...............................

DAILY RECORD OF MILK YIELD

Day	Date	Milk yield (ml)		Remarks
		Morning	Evening	
–3				
–2				
–1				
0				
3				
6				
9				
12				
15				
18				
21				
24				

Appendix 5.1 Form to record palatability of tree fodders

PALATABILITY OF TREE FODDER

Animal species ....

Animal number ....

Date ....

Address ....

Experiment day ....

FEEDING TIME [Morning (AM) OR Afternoon (PM)] ....

TIME STARTED.................... TIME FINISHED....................

---

1. FINISHING ORDER

1st ....

2nd ....

3rd ....

4th ....

5th ....

6th ....

2. ANIMAL'S PREFERENCE ORDER [1]

1st ....

2nd ....

3rd ....

4th ....

5th ....

6th ....

3. FODDER INTAKE

Fodder type	Fodder offered	Fodder left	Fodder eaten
Ghotli			
Malbans			
Amliso			
Nebharo			
Gogun			
Dudhilo			

[1] Based on the 'time spent by an animal eating a given tree species', 'frequency of repeat bites' and 'behavior' of individual animal such as tail wagging etc in preference to a fodder type.

Appendix: 5.2 Mean (SD) animal's and farmers' preference order for all animal types by AM and PM under on-farm and on-station conditions.

Animal species	Tree species	Animal's preference order		Farmer's preference order	
		AM	PM	AM	PM
Buff (n=8) (On-station)	*Malbans*	1.81(0.46)	1.38(0.44)	2.69(1.51)	3.94(1.29)
	Amliso	4.00(0.46)	3.94(0.18)	2.75(0.89)	2.69(0.84)
	Ghotli	5.75(0.38)	5.94(0.18)	4.38(1.36)	3.88(1.22)
	Nebharo	2.44(0.42)	2.88(0.35)	4.00(0.60)	3.13(1.19)
	Gogun	5.13(0.35)	5.06(0.18)	5.31(1.00)	5.38(0.88)
	Dudhilo	2.00(0.46)	1.81(0.37)	1.88(0.79)	1.94(0.73)
Cattle (n=8) (On-farm)	*Malbans*	2.96(0.70)	2.86(0.79)	3.04(0.72)	3.15(0.89)
	Amliso	3.59(0.74)	3.26(1.04)	3.96(0.82)	3.88(1.04)
	Ghotli	3.96(0.75)	3.96(0.82)	4.08(0.80)	3.69(0.83)
	Nebharo	3.72(1.04)	3.67(1.17)	3.64(1.01)	3.50(0.82)
	Gogun	4.76(1.30)	5.00(1.15)	4.80(1.44)	4.83(1.51)
	Dudhilo	2.01(1.05)	2.42(1.44)	1.48(0.56)	1.96(0.97)
Cattle (n=8) (On-station)	*Malbans*	1.94(1.02)	1.94(0.68)	2.88(0.79)	3.88(0.88)
	Amliso	3.44(0.68)	4.00(0.27)	3.13(1.13)	2.56(1.15)
	Ghotli	5.63(0.69)	5.75(0.53)	5.38(0.74)	5.31(1.03)
	Nebharo	2.88(0.88)	2.19(0.65)	2.94(0.56)	3.00(0.93)
	Gogun	4.69(0.59)	5.25(0.38)	5.13(0.44)	4.88(0.58)
	Dudhilo	2.44(0.86)	1.94(0.56)	1.56(0.78)	1.38(0.52)
Goats (n=8) (On-farm)	*Malbans*	5.40(0.37)	5.48(0.32)	4.48(0.54)	4.28(0.28)
	Amliso	3.23(0.38)	3.20(0.24)	3.95(0.53)	4.28(0.75)
	Ghotli	5.28(0.66)	5.40(0.51)	4.68(0.53)	4.73(0.52)
	Nebharo	1.90(0.30)	1.90(0.32)	2.20(0.30)	1.90(0.55)
	Gogun	3.85(0.45)	3.83(0.46)	4.03(0.65)	4.23(0.49)
	Dudhilo	1.38(0.23)	1.30(0.21)	1.75(0.33)	1.70(0.28)
Goats (n=8) (On-station)	*Malbans*	5.85(0.23)	5.83(0.29)	5.73(0.24)	5.83(0.20)
	Amliso	4.40(0.47)	4.08(0.38)	4.30(0.47)	4.18(0.31)
	Ghotli	4.23(0.80)	4.38(0.45)	4.38(0.79)	4.45(0.33)
	Nebharo	2.03(0.20)	2.30(0.34)	2.28(0.40)	2.30(0.32)
	Gogun	3.33(0.30)	3.40(0.19)	3.23(0.33)	3.20(0.37)
	Dudhilo	1.13(0.15)	1.00(0.00)	1.10(0.11)	1.03(0.07)

Appendix 7.1 Potential gas production (PD) in PEG (Polyethylene glycol, 8000) treated and untreated samples. (Analysed at Macaulay Land use Research Institute (MLURI), Aberdeen, Scotland)

Tree species	PEG treated	Untreated
Malbans	36.3	31.0
Badahar	64.5	59.9
Amliso	42.2	31.8
Nebharo	39.9	36.6
rai khanyu	34.4	31.2
rato siris	47.0	40.1
kabro	44.0	49.6
tanki	36.2	26.6
patmiro	44.5	40.7
dudhilo	60.5	56.9
khasre khanyu	55.7	44.4
gogun	49.1	32.5
bhimsenpati	21.3	22.6

Appendix 7.2 Interaction between tree species and season on potential gas production of tree leaves

Season	mid March/mid June	mid Nov/ mid Jan	mid Jan-mid March
malbans	41.67 (1.01)	39.47 (1.01)	40.42 (0.91)
badahar	62.71 (1.01)	66.83 (1.01)	64.02 (1.18)
amliso	42.94 (1.01)	37.45 (1.01)	37.46 (0.91)
nebharo	46.38 (1.01)	45.26 (1.01)	44.74 (1.18)
rai khanyu	37.00 (1.01)	41.85 (1.01)	39.02 (0.91)
rato siris	45.01 (1.01)	47.87 (1.01)	48.01 (2.14)
kabro	57.60 (2.02)	55.69 (2.02)	56.54 (1.43)
tanki	45.18 (1.01)	42.62 (1.01)	41.08 (1.18)
patmiro	45.26 (1.01)	43.97 (1.01)	45.00 (0.91)
dudhilo	61.48 (1.67)	62.87 (1.20)	61.05 (1.20)
khasre khanyu	54.35 (1.18)	51.78 (1.01)	50.62 (1.01)
chuletro	61.97 (1.01)	57.56 (1.01)	57.95 (2.14)
gogun	48.62 (1.01)	49.57 (1.01)	50.80 (0.91)
bhimsenpati	45.14 (1.01)	43.18 (1.01)	42.84 (0.91)

Figures in parentheses are standard error of mean (SEM)

Appendix 7.3 Interaction between site and tree species on potential gas production

Tree species	Fakchamara	Patle
Malbans	41.6 (0.77)	39.4 (0.82)
Badahar	65.1 (0.82)	63.9 (0.92)
Amliso	40.4 (0.77)	38.2 (0.82)
Nebharo	43.9 (0.92)	47.1 (0.82)
rai khanyu	41.0 (0.77)	37.6 (0.82)
rato siris	47.5 (1.26)	46.5 (0.95)
Kabro	54.5 (0.95)	58.7 (2.52)
Tanki	42.5 (0.82)	43.5 (0.92)
Patmiro	45.6 (0.77)	43.9 (0.82)
Dudhilo	61.9 (0.93)	61.7 (1.37)
khasre khanyu	51.7 (0.82)	52.8 (0.92)
Chuletro	59.3 (1.26)	59.1 (0.95)
Gogun	49.9 (0.77)	49.4 (0.82)
Bhimsenpati	44.9 (0.77)	42.5 (0.82)

Figures in parentheses are standard error of mean (SEM)