Feeding the Herds

Improving Fodder Resources in Bhutan

Walter Roder
Kinzang Wangdi
Pema Gyamtsho
Karma Dorji

about ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD)is an international organisation devoted to development of the Hindu Kush-Himalayan region covering all or parts of eight sovereign states. Active areas include Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. The Centre is located in Kathmandu, Nepal. The primary objective of the Centre is to promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations.

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Foreword

Bhutan is still a country of herders and farmers. Livestock rearing has always been an important source of livelihood for the Bhutanese, ranging from buffaloes in the southern foothills to yaks in the high altitude regions along the northern border. Traditional livestock production systems are largely based on free grazing on natural grasslands and forests. With the transition of the rural economy from subsistence to a cash economy, improvement of the feed and fodder resources will be vital for optimising returns from livestock rearing as poor animal nutrition is one of the major constraints in achieving higher levels of production.

Having realised the importance of fodder development in modernising the livestock sector, the Royal Government of Bhutan has carried out a well-focused research programme on temperate fodder production since the 1970s. This has had a substantial impact on livestock production in the country not only in terms of increased milk production and consumption, but also in reducing cattle migration, improving soil fertility and decreasing soil erosion. Without improved pastures, it would not have been possible to support the newly introduced breeds of cattle like Jersey and Brown Swiss.

Bhutan has limited resources for research and development activities. Yet the wide range of environments and the very diverse production systems pose a tremendous challenge to the research system entailing rigorous prioritisation of research areas. It is, therefore, of outmost importance to learn from the past and avoid repetition of efforts and wastage of the scarce resources. This document represents the first comprehensive review on feed and fodder development activities carried out in Bhutan, as such it will serve as an invaluable repository of knowledge in this field.

In successfully bringing out this publication, I would like to compliment the Renewable Natural Resources Research Centre, Jakar, in particular, the authors and the contributors. The farmers and herders who willingly shared their wealth of experiences also deserve our highest praise. I extend my sincere appreciation to ICIMOD for editing and publishing this valuable document. I am sure that this attractive book will be widely used within and outside Bhutan by farmers, herders, extension agents, researchers, planners and policy makers. Through ICIMOD's established network, I hope that the experiences from Bhutan will be accessible and useful to other regions that share similar agro-ecological and socio-economic conditions.

Lyonpo Kinzang Dorji
Minister for Agriculture
Royal Government of Bhutan
Thimphu, November 18, 2001

Foreword

The country of Bhutan, which is completely mountainous, faces many of the challenges inherent to neighbouring countries of the HKH. Inaccessibility and marginality characterise its landscape. However, the people of Bhutan exhibit an amazing ability to adapt and harness the country's rich resources, especially through their livestock, which form the basis for their diverse farming systems.

Although it is not facing the population pressures seen in other nearby regions, Bhutan is facing its own unique set of challenges as it modernises and enters the market economy, while simultaneously attempting to preserve its unique culture. The development of its livestock sector is of prime importance. As in other parts of the Himalayan region, fodder is a significant limiting factor for livestock production. The Royal Government of Bhutan recognised this issue long ago and initiated numerous livestock development programmes, of which fodder development has been and continues to be a significant component.

ICIMOD is committed to assisting countries like Bhutan with their efforts in livestock and pasture development and, with this aim, initiated a rangeland programme in 1995. In 1996, ICIMOD provided assistance to the Bhutan Ministry of Agriculture to compile a review of the literature on the significant advancements Bhutan has made in the forage development sector. This review was completed in 2001, drawing on over 40 years of research experience in the country. This publication reflects this rich knowledge base.

This review of forage and fodder research in Bhutan is a comprehensive document that provides both a wealth of technical information and also a good insight into the legislative and farming systems framework for Bhutan's forage development programme. Such information will be invaluable for anyone undertaking forage work within Bhutan, but is also of great interest for those attempting programmes in other parts of the region, where a less systematic approach is generally the norm. The volume of work completed and reported is remarkable, particularly so in the context of the major shortage of trained manpower. The historical sections provide evidence of the time frame needed to achieve significant results, and underlines the difficulties most programmes encounter with unrealistically short implementation periods and frequent changes in organisational structure.

The document represents an enormous effort in compilation and will be valuable for all of us in the region. We hope that it will lead to a more regular dialogue across the region among livestock and forage professionals, government policy makers and those working at the grassroots level.

The funding for this publication has been generously provided through a grant from the Federal Government of Austria for ICIMOD's Regional Rangeland Programme with some support from Helvetas-Bhutan.

J. Gabriel Campbell
Director General, ICIMOD

Acknowledgements

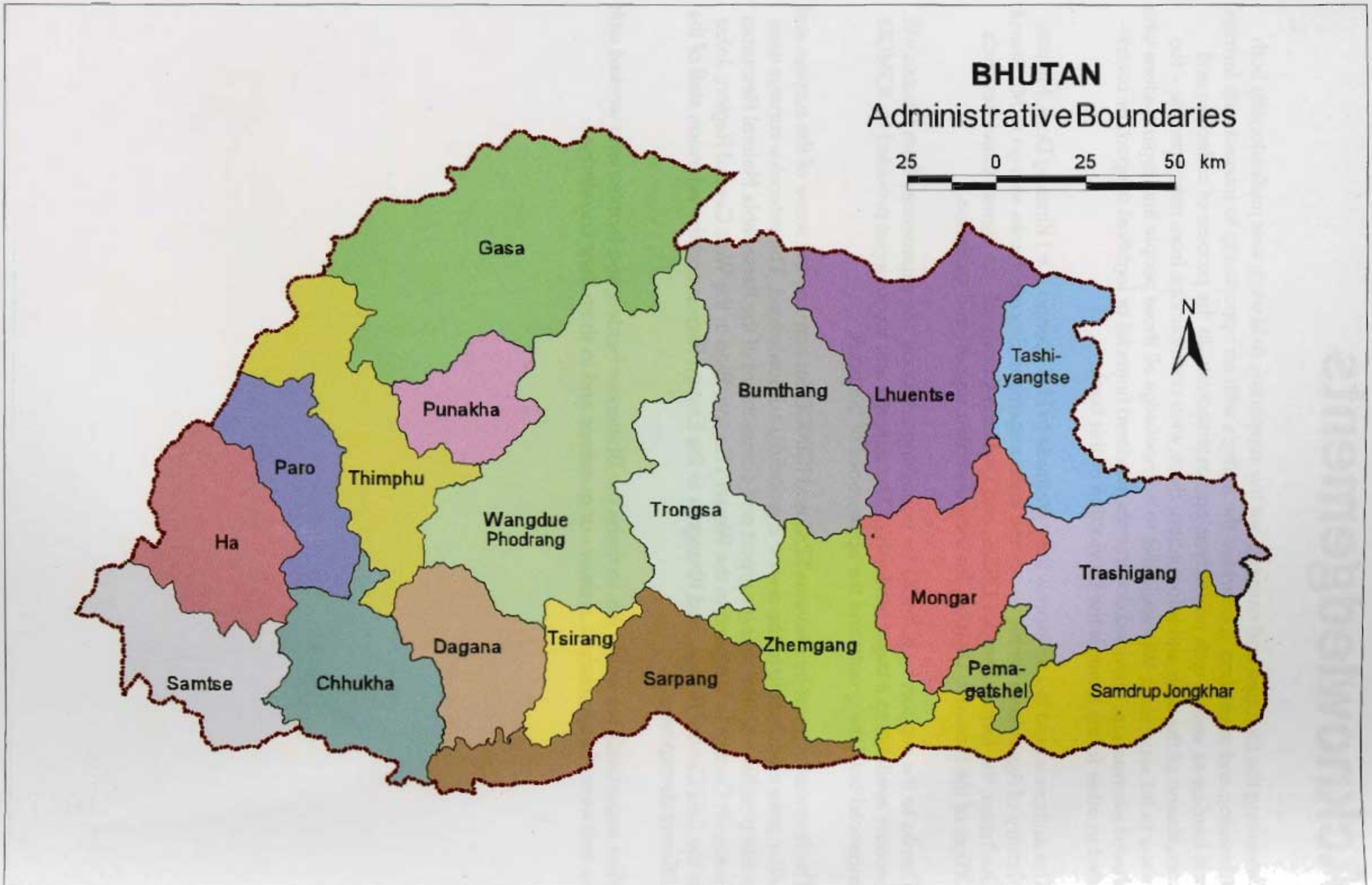
Reviewing the literature and carrying out the supporting field work was professionally both interesting and rewarding. It provided the authors with an opportunity to interact with farmers and herders as well as with researchers and extensionists. In the process of collection and compilation of the data and information, there were contributions from many people – too many to list separately. We would like to acknowledge all those people and organisations who shared information, provided documents, rendered financial or logistical support, or contributed in other forms towards the production of this book.

The authors would like to express their gratitude to H.E Lyonpo (Dr.) Kinzang Dorji, Minister, Ministry of Agriculture for his vision and encouragement. Sincere thanks also go to Mr. Sherub Gyaltshen, the former Director DRDS, and Dr. Pema Choephyll, the former Chief Research Officer of the Research Division, for their unstinted support and guidance.

Thanks to the support by ICIMOD for publishing this book, the experiences from Bhutan will become available to a larger readership. The editorial and layout input provided by ICIMOD enhanced both the quality and the appearance of the book.

The financial support by Helvetas/SDC and ICIMOD for carrying out some of the surveys and other tasks contributing to the review is gratefully acknowledged. The extensive surveys were made possible with the strong support and commitment of the Renewable Natural Resources Research Centres in Yusipang in the Western Region, Bajo in the West Central Region, Jakar in the East Central Region, and Khangma in the Eastern Region and the extension staff of the different dzongkhags.

Most importantly we would like to thank the Bhutanese herders and farmers who worked with us and were always ready to answer our questions and to share their knowledge.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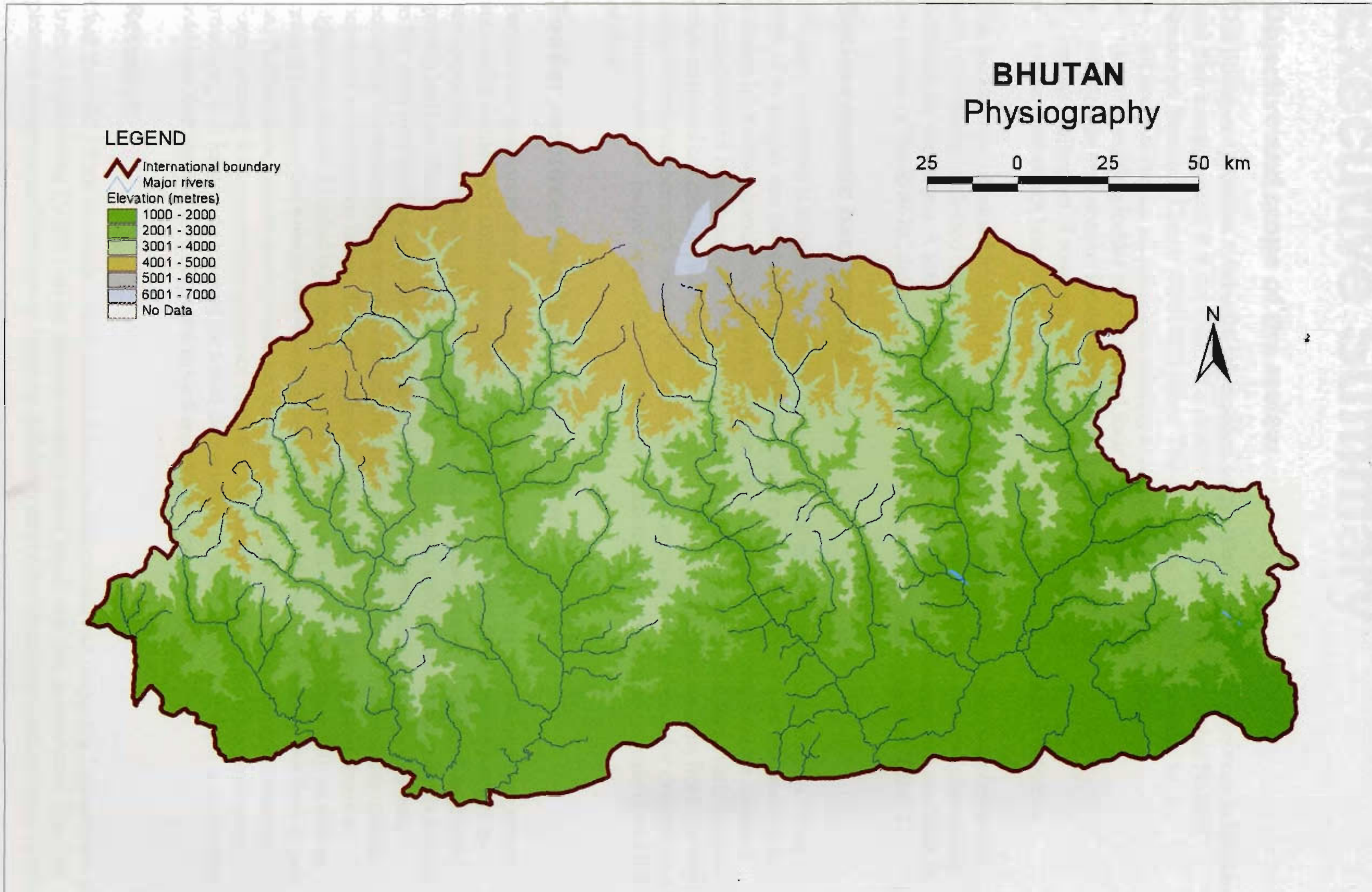
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Executive Summary

Objective and scope of the review

This document provides substantial information on grassland and fodder resources in Bhutan and their management. It is the result of a review carried out by the Renewable Natural Resources Research Centre (RNR-RC) Jakar. The objectives of this review were to

- list and summarise all references relating to fodder resources in Bhutan;
- describe existing fodder resources and their management;
- summarise and analyse fodder research and extension activities;
- assess the impact of research and extension at the farmers' level; and
- create a reference base for the planning of future research and extension activities.

The information obtained from the numerous available references has been supplemented with information collected from various surveys planned and carried out as complementary activities for the review. A total of 276 references are listed. These references are available in the library of the RNR-RC Jakar and copies of the majority will also be held at ICIMOD.

Socioeconomic background

Bhutan's economy is strongly influenced by its historical and geographical isolation. Over 80% of its people are involved in activities related to agriculture; only 8% of the country is suitable for arable agriculture, however. Bhutan has a comparative advantage for livestock production and has about 336,000 large ruminants (cattle and yak). The large variations in environmental conditions provide a wide range of livestock production systems from the high altitude transhumance yak system to systems in which animals are used only for draught and manure purposes. In the year 2000, livestock production was estimated to provide about 8% of GDP.

Fodder resources and their management

Permanent grasslands, forest grazing, and the grazing of fallow land are the most important sources of fodder and contribute over 70% of total fodder needs. Other important fodder resources are crop residues and tree fodder. The country has over 400,000 ha of registered grazing land or about 1.2 ha per large ruminant (cattle and yak). These grazing lands belong to the state and herders only have the grazing rights. The dominant fodder species vary according to elevation, environmental conditions, and management. Grass species usually dominate at elevations below 3500m. Sedges and broadleaved species are dominant at higher elevations. Limited by rainfall, available phosphorus (P) and nitrogen (N), as well as grazing practices, the annual dry matter production of grasslands is generally less than 2t per ha. Furthermore, fodder quality declines rapidly towards the end of the monsoon season. Forest grazing is an important source of ruminant fodder and fertiliser for crop production (manure). It is frequently blamed for forest degradation or destruction, but there is increasing evidence that grazing is not harmful in well-managed conifer forests.

Research

Until the mid-1990s livestock fodder research was mostly carried out under the Department of Animal Husbandry (AHD) and by various projects associated with this department. The first planned experimental activities to focus on fodder resource development were initiated by the

Rural Development Programme (RDP) (Bumthang) in 1974. The Ministry of Agriculture was reorganised in 1995, when four Renewable Natural Resources Centres (RNR-RCs) were established. Research activities in the livestock sector (including feed and fodder) are coordinated by the RNR-RCs Jakar, which is located in the temperate region of central Bhutan. The major research findings are as follow.

Evaluation of native species – The plant communities of the major grassland ecosystems remain poorly documented. An indication of nutritional qualities is available only for the two grassland species *Schizachyrium delavayi* and *Lespedeza* sp, and for less than 20 woody perennials. Of all the native species, willow (*Salix babylonica*) has received the most attention.

Germplasm introduction and testing – Since the mid 1970s, 75 grass species and 157 legume species have been introduced and evaluated. About 50% of all the species evaluated were introduced into Bhutan before 1983. Similarly, all species – except for ruzi grass (*Brachiaria ruziziensis)*, which is presently being recommended for extension – were selected before 1982. Generally, white clover *(Trifolium repens)*, red clover *(T. pratense)*, lucerne *(Medicago sativa)*, and lotus *(Lotus pedunculatus)* have been the highest yielding legumes under temperate conditions. The highest yielding grass species have been cocksfoot *(Dactylis glomerata)*, tall fescue *(Festuca arundinacea)*, and Italian rye grass *(Lolium multiflorum)*.

Establishment – Investigations into the establishment of fodder species led to the recommendations for the introduction of white clover by direct seeding or transplanting, and establishment of recommended species by relay seeding in cultivated crops.

Fertility management – Poor P availability strongly limits plant growth in the temperate regions. Studies have focused on P rates, P fertilisers, local P fertiliser substitutes, legumes' P requirements, N effects on yield and species composition, and K requirements in subtropical regions. At elevations of between 2600 and 3700m, P application can result in dry matter yield increases of between 6% and 800%.

Winter fodder – Studies have been conducted on methods of conservation, the introduction of arable annual fodder crops, and the use of tree fodders. Keeping dry matter standing in the fields for grazing between December and February appears to be the most economical form of conservation for temperate regions. Oats *(Avena sativa)*, swede *(Brassica napus)*, hairy vetch *(Vicia villosa)*, and rye *(Secale cerale)* have been identified as suitable winter fodder crops for temperate regions.

Nutritional qualities – Analytical data and information on intake and animal production was generated for a range of tree fodders.

Seed production – Seed production studies were carried out and suitable seed production techniques were developed for white clover, cocksfoot, and greenleaf desmodium *(Desmodium intortum)*. Additional research is necessary for the other species.

Integrated studies – Studies have been carried out on crop rotation, cropping sequences, combinations with fruit trees, and silvopastoral systems.

Extension and its impact

The AHD began to build up a network of extension centres in the 1970s. The earliest documented and sustained extension activities focusing on fodder development started in

Bumthang dzongkhag (administrative district) in 1978. The species promoted at present are white clover, Italian rye grass, cocksfoot, tall fescue, ruzzi grass, molasses grass *(Melinis minutiflora)*, greenleaf desmodium, oats, and hairy vetch.

The extension activities during the Fifth to Seventh plan period (1982-1997) resulted in the development of 13,760 ha of pasture and the planting of 735,819 fodder trees. In addition, white clover has been spread naturally by grazing animals and through manure application.

The strongest impacts have been achieved through the introduction of white clover combined with the application of P-fertiliser. It has been estimated that in some areas fodder development activities have increased dry matter production by 10%, the quality of fodder during the summer by 50%, the quality of fodder during the winter by 200%, and milk production by 500%. The increased milk production has improved nutrition in rural and urban areas and provided substantially increased cash incomes for many households. The promotion of tree fodders has been another important component of the extension programme. Activities in subtropical regions have been less successful. The treatment of paddy straw with urea has not been adopted.

Constraints

Limited landholdings and problems related to land tenure are often cited as the major constraints to fodder development activities, but a range of factors contributes to the situation. They include difficulties with the rules and legislation, social customs, and traditions; competition for other land use; unsuitable technologies; and the difficulties in processing and marketing of livestock products. Most farmers give a low priority to fodder resource development because their animals are not productive enough to respond to better feed and because the technologies offered are sometimes inappropriate. The socio-religious taboo that forbids the killing of animals, the concentration of large cattle herds with a limited number of households, and the traditional seasonal migration of livestock further slow the transition to a more productive system.

Future directions

The Royal Government of Bhutan is strongly committed to improving the nutrition and increasing the incomes of its rural population, while at the same time maintaining or improving the biophysical resources of the country. To achieve this goal, livestock production systems will have to

- produce livestock products for a fast growing urban population;
- make a positive contribution towards maintaining the overall biophysical resources;
- provide equitable income opportunities for the rural population; and
- complement field crop, horticulture, and forestry production systems by exploiting synergistic effects, optimising labour efficiency, and accelerating nutrient cycling.

Research and extension have an important role to play in transforming production systems. The limited resources available for research across Bhutan's wide range of environmental conditions demands a rigorous setting of priorities. Future research programmes need to be flexible, realistic, and simple. Whilst drawing up future plans, imaginative interventions should be given as much attention as drawing on the experiences of earlier extension programmes. The success of future extension activities will largely depend on the availability of human resources and of appropriate technologies generated by the research programmes.

Glossary

Bhutan specific terms

ara	home-made alcoholic beverage distilled from fermented grain of wheat, barley, maize, rice or millet
chang	any alcoholic drink; in this document 'chang' refers to fermented wheat, barley, maize or millet
dzongkhag	administrative district; Bhutan has 20 dzongkhags (see map)
geog	sub-unit of a dzongkhag (also called block)
lac	resinous secretion from the insect *Laccifer lacca*, used as a dye
maund	unit of weight, in Bhutan 1 maund is approximately 40 kg
mithun	(*Bos frontalis*) a semi-domesticated animal reared in Arunachal Pradesh in India which has been used in cross-breeding programmes with Bhutanese cattle breeds
ngultrum (Nu)	Bhutanese currency unit
pangshing	Bhutanese term for a grass fallow shifting cultivation system used in temperate areas
Shabdung	title of the unifier of Bhutan and his reincarnations (literally 'at whose feet one prostrates')
tsadrog	land registered as grazing land; it is state property and herders and farmers only have grazing rights
tsheri	Bhutanese term for a shrub-fallow shifting cultivation system used in sub-tropical areas

Terms specific to grazing land and fodder resources[1]

arable fodder	fodder species grown on land commonly used for crop production
crop residue	the part of plants remaining after harvesting the main produce
cut and carry	systems in which fodder is cut and brought to the animals for consumption
feed	any fodder for livestock, especially concentrates, grains, by-products of milling, and other types
fodder or forage	non-woody plant biomass that is potential food for farm animals
fodder resource	any plant biomass used as fodder
forest grazing	herbaceous undergrowth in forests (land registered as forest with variable tree cover) consisting of grasses, sedges, broadleaved species, and shrubs palatable to grazing animals
grassland	land on which grasses, sedges, and/or herbaceous broadleaved species such as legumes constitute the dominant vegetation

[1] Glossary of terminology adapted from the terminology suggested in RNR-RC Jakar (1996a): Proceedings of the 1st National Feed and Fodder Workshop, pp. 57-59, Annex 4.13 Suggested Terminology

grazing land	any vegetated land that is grazed or has the potential to be grazed by animals
grazing	the direct consumption of (unharvested) fodder by animals
improved pasture or improved grassland	grazing land which has been improved through species additions and/or management interventions, or which has been established on shifting cultivation or cropland
natural grassland	land used for grazing with a vegetation community dominated by grasses and sedges as a result of some natural biophysical limitation — including effects of grazing animals — that precludes the growth of shrubs or trees; also includes high elevation grazing lands above the tree line, which often have a significant shrub component, thus the term 'grassland' is used here in a broad sense to refer to natural rangeland ecosystems (naturally existing grassland or shrubland)
palatability	plant characteristics that stimulate a selective intake response by the animal
pasture	another word for 'grazing land'
permanent grassland or permanent pasture	similar to natural grassland but also includes improved grasslands that are maintained continuously as grassland pasture (also those maintained by human disturbances such as fire)

Acronyms and Abbreviations

AHD	Animal Husbandry Department
ARC	Agriculture Research Center
CSO	Central Statistical Office
DM	dry matter
FAO	Food and Agriculture Organization of the United Nations
FSP	Forages for Smallholders Project
GAFRC	Grassland and Associated Fodder Research Centre
GDP	gross domestic product
HAADP	Highland Altitude Area Development Project
HLDP	Highland Livestock Development Programme
IFDP	Integrated Forestry Development Project
ISDP	Integrated Sustainable Development Programme
LUPP	Land Use Planning Project
MOA	Ministry of Agriculture
NEC	National Environment Commission
NES	National Environment Secretariate
NRTI	Natural Resources Training Institute
NFSPC	National Fodder Seed Production Centre
PPD	Planning and Policy Division (RGOB Ministry of Agriculture)
RDP	Rural Development Programme
RGOB	Royal Government of Bhutan
RNR-RC	Renewable Natural Resource Research Centre
SDR	summed dominant ratio
STFRC	Subtropical Fodder Research Centre

NOTE

Currency

The Bhutanese currency unit is the Ngultrum (Nu). It is tied to the Indian rupee at par: 1Nu= 1 IR

Approximate rate of exchange in 2001: $US 1 = 47.5 Nu

Five-Year Plans

Planning is based on a five-year cycle. The year runs from July to June
The relevant dates are as follow.

5th Five-Year Plan Period	1982 - 1987
6th Five-Year Plan Period	1987 - 1992
7th Five-Year Plan Period	1992 - 1997
8th Five-Year Plan Period	1997- 2002

Contents

Chapter One
Introduction

Bhutan is located in the eastern part of the Hindu Kush-Himalayan region (HKH). Precipitation in many parts of the country is considerably higher than in most other parts of the HKH. Nevertheless, Bhutan shares many of the vegetation, climatic, and socioeconomic characteristics of its immediate Eastern Himalayan neighbours, especially the south-eastern Tibetan region of China and the Sikkim and Arunachal region of India. As in many parts of the HKH, Bhutan's livestock production systems are largely based on natural grassland resources. However, sentiments against culling animals have limited the scope for the meat industry and for selective breeding, as in much of the Buddhist region of the Tibetan Plateau.

Bhutan also has many unique features.

- It is the only country in the HKH region that is exclusively mountainous.
- As a result of its low population density, the landholdings in Bhutan's temperate belt are generally larger than in other HKH countries.
- It has a much higher proportion of forest cover and a remarkable biodiversity.
- It possesses a great diversity of agricultural production systems.
- It's domesticated bovine species are diverse: they include yak *(Poephagus grunniens)*, cattle (*Bos taurus* and *Bos indicus)*, mithun (*B. frontalis*), and buffalo *(Bubalus bubalus)*, which are raised under a diverse array of animal husbandry systems.
- Bhutan initiated development activities relatively late compared to other countries in the region.
- Unlike in most other HKH countries, the population living in the mountains is in the majority. This has led to a strong commitment on the part of the government to work with mountain farmers and herders to improve their livestock production systems.

Bhutan is a small country and has only limited resources to invest in research and the development of fodder resources. In spite of this, the well-focused research activities on temperate production systems carried out during the 1970s and 1980s have had a substantial impact on livestock production systems in the country. These achievements have been recognised by forage and livestock specialists from neighbouring countries, and some of the experiences and technologies will be of interest to forage and livestock specialists and others interested in fodder resources development in other parts of the HKH. This book focuses on the experiences and achievements related to fodder production, rather than those concerned directly with livestock. Those in temperate regions may be interested to learn from Bhutan's experience with seed production systems and methods for establishing temperate fodder species, with forage systems using willow in combination with white clover, or with using turnip and pumpkin for fodder in mixed livestock farming systems; those in sub-tropical regions will find useful experience with plantation systems such as citrus and mango combined with fodder peanut (*Arachis pintoi*). Last but not least, many will be interested in the way in which livestock, crops, horticulture, and forestry are integrated in a single research and extension system across the country – an approach that could be usefully replicated elsewhere at mountain research stations and lower level administrative units such as at the district level, even if not on a country-wide scale.

Fodder resource development in Bhutan

This publication is the result of a review carried out from 1996 to 1998 by the Renewable Natural Resources Research Centre (RNR-RC) in Jakar, Bumthang to evaluate and document 30 years of research and development activities in Bhutan's fodder resource sector.

The early 1960s saw rapid changes in Bhutan with the building of roads, the introduction of a modern school system and a policy limiting land ownership. At the same time, government sponsored programmes were initiated to provide support for farmers in livestock development (Tenzing 1978). These programmes gathered momentum with the creation of a separate Animal Husbandry Department (AHD) in 1963.

Early on it was recognised that any improvement in livestock production depended on improving the quantity and quality of fodder resources. Yet it was only in 1974 that the first methodical feed and fodder research and development activities were initiated (Roder 1996a) by the Dairy and Forestry Project in Bumthang (later Rural Development Project). Thus the bulk of the information used in this review originates from documents written from 1975 onwards (Figure 1).

The commitment and support for fodder development grew steadily throughout the Fifth and Sixth plan periods (1981-1992) with strong inputs from various donor agencies. During the second part of the 1980s the number of research activities decreased whilst support for extension increased.

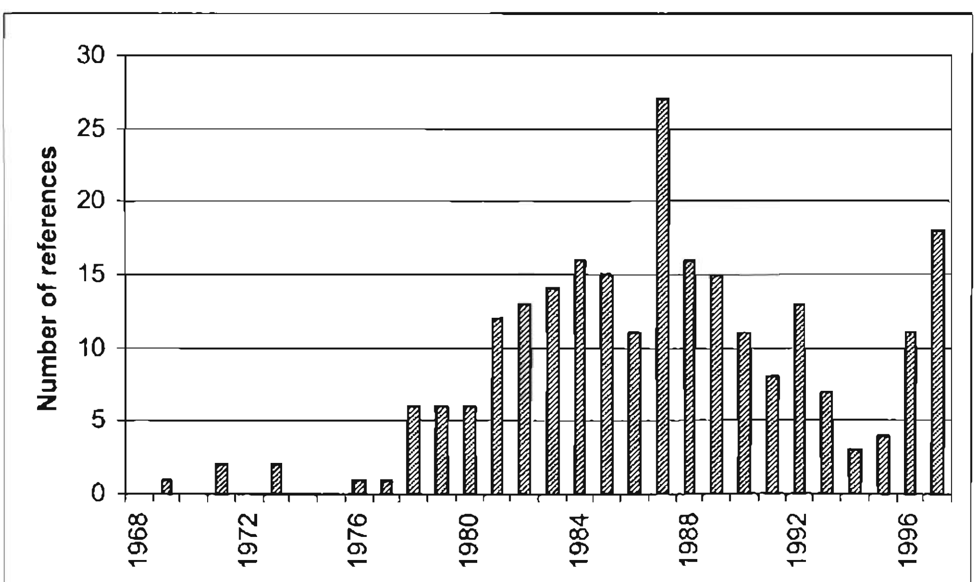

Figure 1: Publications on livestock development in Bhutan with an emphasis on fodder

The number of research activities only started to increase again after the 1994 reorganisation of the Ministry of Agriculture. At this time a new research network was put in place, with a strong commitment to the decentralisation of responsibilities and the integration of all disciplines into regional institutions. Considering these changes and the fact that the Government sponsored research and development activities in livestock production and fodder resources had been running for over 20 years, a need was recognised to review activities, experiences and achievements. To respond to this need the RNR–RC Jakar carried out this review with the following objectives.

- To list and summarise all references relating to fodder resources in Bhutan
- To describe existing fodder resources and their management
- To summarise and analyse past research and extension activities in fodder resources and their management
- To assess the impact of these activities at the farmer level
- To build up a reference base for the planning of future research and extension activities

The information obtained from the many references was supplemented with information collected from surveys carried out between 1996 and 1998 on:

- winter feeding practices of farmers with milking cows (in Bumthang dzongkhag [district]);
- rice paddy straw treatment (farmers assessments were collected and the impact of extension activities were measured in selected dzongkhags);
- fodder trees (the importance of tree fodder, the species used, and the impact of extension activities were measured in selected dzongkhags); and
- fodder resources and fodder development (farmers assessments were collected and the impact of extension activities were measured in selected dzongkhags).

This document provides substantial information on the management of grassland and fodder resources by summarising the available documentation. Some comments and opinions have been included by the authors of this review, but these do not necessarily reflect the views of the original authors of the documents that are reviewed.

Socioeconomic background information

Bhutan's economy is strongly influenced by its historical and geographical isolation and remains largely agrarian. Over 80% of its population are involved in agriculture-related activities, and contribute about 41% towards the GDP (PPD 1996). The traditional farming system was strongly influenced by Bhutan's isolation, which required almost complete self sufficiency in food. This was achieved by extensive investments in terracing and irrigation systems and by using labour intensive cultivation practices.

Land use is influenced by climate and topography. Due to Bhutan's mountainous character only a small percentage of its area is suitable for agriculture (Table 1). The main crops that are cultivated are, in order of importance, maize, rice, millet, wheat, buckwheat, potato, mustard and barley.

In 1996 it was estimated that there were 65,000 farming households in Bhutan with an average household size of seven persons (PPD 1996). At that time the country reported a total population of approximately 600,000 (rural and urban). The average landholding size was 1.5 ha with 10% of households having more than 5 ha. Rice is cultivated on small terraces on slopes with gradients of up to 80%. The steep topography and market inaccessibility favour livestock production, especially in regions lying above 2,000m.

Table 1: Land use and livestock statistics		
Land use[1]	**Area ('000 ha)**	**% of country**
Forest	2,904.5	72.5
Lowland rice	38.8	1.0
Upland agriculture (maize, wheat, barley, buckwheat)	181.7	4.5
Shifting cultivation ('tsheri' & 'pangshing')	88.3	2.2
Horticulture (apples, oranges, cardamom)	5.8	0.1
Natural grassland	155.3	3.9
Improved pasture	1.1	<0.1
Total land area	**4,007.7**	**100**
Livestock (1995 data)[2,3]	**Numbers ('000s)**	
Cattle	305.0	.
Buffaloes	1.0	.
Yaks	30.2	.
Equine (horse, mules, donkeys)	25.8	.
Goats	16.0	.
Sheep	31.3	.

Source: [1]MOA 1997a; [2]MOA 1997b
[3] not including pigs and poultry

Livestock production is very important in all Bhutanese farming systems. The large variations in environmental conditions across the country result in a wide range of livestock production systems, ranging from the high altitude transhumance yak system, to systems in which animals are only used for draught and manure purposes. The present livestock production is estimated to contribute about 8% of Bhutan's GDP (Figures 2 and 3). In 1996 milk production was estimated at 10,600t per year (PPD 1996). Since the beginning of the 1980s, programmes to crossbreed local cattle with Jersey and Brown Swiss cattle have had a substantial influence on the structure of the cattle population, the management systems, and milk production.

Figure 2: Traditional livestock products: cheese and butter wrapped in rhododendron leaves

A number of authors have referred to the socioeconomic factors that affect livestock production and the management of fodder resources (Marakham 1876, Fischer 1971; Wangmo 1984; Roder et al. 1987; Guenat 1989; Caron 1994; Dorjee 1995; Gyamtsho 1996). Information is available on transhumance yak production systems (Wangmo 1984; Gyamtsho 1996), cattle production systems (Fischer 1971; Guenat 1989; Ura 1996), and sheep farming systems (Gyamtsho 1996).

Bhutan's legal code is based on an ecclesiastical system initially established by the first Shabdrung[1] in the 17th century. Rules and regulations guiding the use of land resources are specified in the Land Act (RGOB 1991). This legislation specifies that permanent grazing lands (*tsadrog*) are registered as a specific land-use class and cannot be diverted to other uses. Over the past decades, several amendments to the legislation have been formulated to facilitate livestock production (the animal by-laws) and the development and use of the fodder resources (draft pasture policy). Following the Land Act, all registered grazing lands belong to the state and herders only have the grazing rights.

1 The first spiritual and political leader who unified Bhutan.


Figure 3: A herder milking a yak

Early records (before 1975)

Isolated by geographic and self-imposed barriers, Bhutan experienced little or no outside influence until the second half of the twentieth century. Bhutan's rugged topography, its low population density, and its geographic isolation favoured livestock production. Bhutanese farmers and herders have followed traditional practices in well-adapted subsistence farming systems. In the absence of any systematic government-sponsored research and extension programmes, farmers and herders depended on their own curiosity and ingenuity to assess and adopt new technologies from neighbouring regions or develop technologies themselves (Roder et al. 1987). Changes generally took place slowly. A strong impact on the livestock population came about through crossbreeding programmes with mithun cattle *(Bos frontalis)*, which probably began about a hundred years ago. Until 1960, government interventions were largely restricted to tax collection and regulating land ownership (Roder et al. 1987; Ura 1996). For most families livestock and property were the only investment opportunities.

The earliest accounts of Bhutan's vegetation are those given by Griffith (1839) and Schweinfurth (1957). Griffith's travelogue of his 1838 journey gives an interesting glimpse of Bhutan's vegetation along a route leading from Eastern Bhutan through Bumthang to Thimphu (1839). Griffith made a few remarks about cattle management. He was surprised by the poor condition of the animals and the poor feed provided to them. Records from other early travellers give us some insights into agricultural and herding practices (Kuloey 1865; Marakham 1876). However, they rarely discussed the vegetation cover or other aspects that relate to livestock fodder. White (1909) made some interesting observations about forests and suggested that the Bhutanese had acquired the secret of combining the regeneration of forests with unlimited grazing.

Prior to 1960, most grazing lands and a large percentage of the cattle and yaks were owned by a few prominent families and by the monasteries (Roder et al. 1987). Grassland use and livestock management were largely influenced by these owners of the large, migrating cattle herds. Data from 1837 show livestock commodities such as ponies, yak tails, and musk as among Bhutan's most important export items (Table 2).

Table 2: Bhutanese products exported to India through Rungpore in 1837

Product	Unit	Quantity	Value[2] (Rs)
Hill ponies	no.	100	3,500
Yak tails	maunds[1]	4	160
Musk	no.	50	100
Wax (bee)	maunds	30	1,000
Walnuts	no.	50,000	125
Lac	maunds	10	100
Madder – a plant product used as dye	maunds	500	1,500
Blankets	nos.	300	600

[1] Approximately 40kg, [2] Indian currency as valued in 1837
Source: Kuloey 1865

Following visits to Bhutan in 1969 and 1971, Fischer (1971) recommended the following measures to improve livestock production:

- clear pasture areas of brush and other weedy vegetation;
- divide grazing lands into smaller units and fence them with hedges (he recommended using evergreen oak, *Quercus semecarpifolia*, and said that some of the hedge plants could be left to grow into trees);
- cultivate grasses and other suitable herbs as cattle fodder;
- avoid using imported fertiliser;
- keep cattle in stables and use the dung as fertiliser; and
- introduce silage making (the author suggested that hay making may not be possible because of the wet monsoon climate).

Despite the clear historical record of the importance of livestock in the local economy, the Royal Government of Bhutan (RGOB) did not begin concerted efforts in livestock or fodder development until the 1970s. This was because the government had no advisory or research establishment for agriculture or livestock prior to the establishment of the modern government system in 1961.

Chapter Two
Fodder Resources and Their Management

Background information

Topography, geology and soils

George Bogle described Bhutan's topography as: "A succession of lofty and rugged mountains, separated by gorges and a few valleys somewhat wider than the generality of ravines" (Marakham 1876). The elevation ranges from about 200m in the south to almost 8,000m in the north. The physical features of the country are described in Karan (1967). Based on a comprehensive geological study of the Bhutan Himalayan chain, Ganser (1983) defined five geological zones: the Sub-Himalaya, the Lower Himalaya, the High Himalaya, the Tibetan Himalaya, and the Indus-Tsangpo zone. Geologically the larger part of Bhutan consists of crystalline sheets with large masses of tertiary granite intrusions towards the north.

Little information is available about Bhutan's soil. The FAO/UNESCO soil map (FAO/UNESCO, 1977) classified about 27% of the country as having either cambisol or fluvisol soils. Cambisols are most common at middle altitudes, while fluvisols mostly occur in the southern belt. Less fertile acrisols, ferrasols, and podzols are estimated to cover about 45% of the country. The same study claimed that 21% of the soil-covered area is only shallowly covered, mostly with lithosols on steep slopes.

Bhutan's forest soils have been classified by Sargent et al. (1985) and Okazaki (1987). Okazaki delineated five major soil groups (Figure 4) based on 69 samples collected from sites between 150m and 5,300m. Altitude and precipitation were the major factors used in this classification.

Soil analysis data are available for a range of sites and cultivation practices in Bhutan (Roder 1982a). There is a wide variation in the availability of macro- and micro-nutrients. In most areas in Bhutan's High Himalaya zone, soils are poor in phosphorous (P) but have sufficient reserves of potassium (K).

Climate and vegetation

Bhutan's climate is dominated by the Indian monsoon with high levels of precipitation between June and September. The winter season is generally dry. The wide range of topography and elevation leads to Bhutan having a wide variety of climatic conditions. A detailed review of the climatic data available for Bhutan's temperate regions has been given in a recent review by RNR-RC Jakar (Roset 1998). This review is of special interest because of the long span of

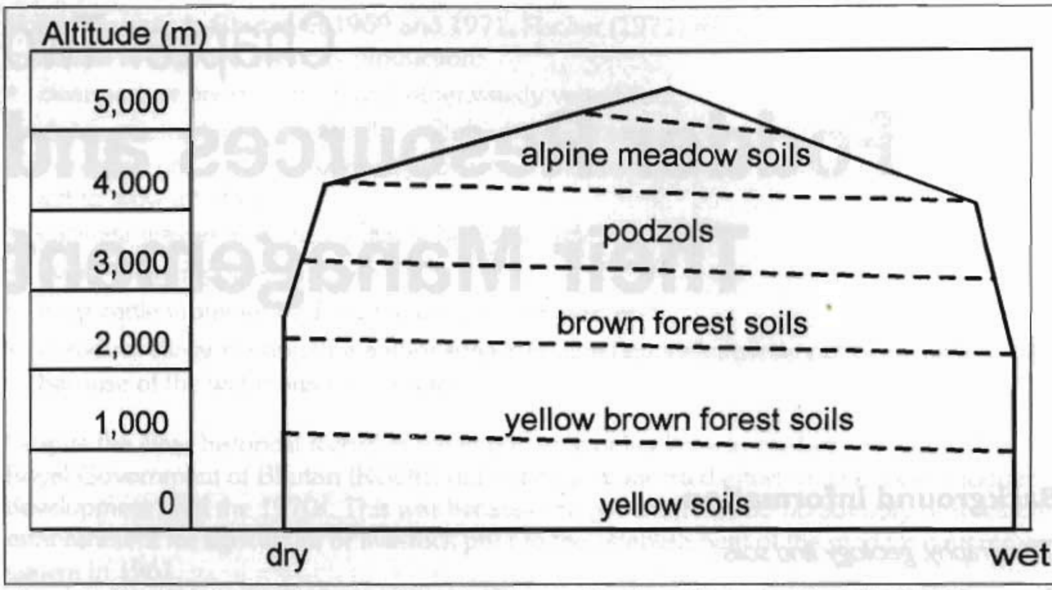

Figure 4: Vertical distribution of soils in the Bhutan Himalaya (Source: Okazaki, 1987)

the available measurements and the high density of meteorological stations sited in Bumthang dzongkhag. The data shows that in Bumthang a 100m increase in elevation gives an average decrease in temperature of 0.55°C, resulting in a decrease in the growing season of about 12 days.

Various attempts have been made to classify Bhutan into agroecological or vegetation zones (Grierson and Long 1983; Negi 1983; Oshawa 1987b; MOA/ISNAR 1992; Gyamtsho 1996). At present, the Ministry of Agriculture recognises the following six zones: wet subtropical (150-600m), humid subtropical (600-1,200m), dry subtropical (1,200-1,800m), warm temperate (1,800-2,600m), cool temperate (2,600-3,600m) and alpine (3,600-4,600m) (MOA/ISNAR 1992). This classification is only a crude simplification as the distinction between vegetation types and the demarcation along altitudinal and rainfall gradients is much more complex on the ground.

Table 3: Vegetation zones in Bhutan (after Grierson and Long 1983)

Dominant species	Altitude (m)	Rainfall (cm)
Subtropical forest	200-1,000	250-500
Warm broadleaf forest	1,000-2,000	230-400
Chir pine *(Pinus roxhburgii)* forest	900-1,800	100-130
Cool broad-leaf forest	2,000-2,900	250-500
Evergreen oak *(Quercus semecarpifolia)* forest	2,000-2,600	200-300
Blue pine *(Pinus wallichiana)* forest	2,100-3,000	70-120
Spruce *(Picea spinulosa)* forest	2,700-3,100	50-100
Hemlock *(Tsuga dumosa)* forest	2,800-3,100	130-200
Fir *(Abies densa)* forest	3,300-3,800	≥130
Juniper/rhododendron	3,700-4,200	-[1]
Dry alpine scrub	4,000-4,600	-[1]

[1] No rainfall estimate given

Grierson and Long (1983) classified Bhutan's vegetation into 11 zones and compared their classification to earlier published systems from neighbouring regions. Their classification is probably the best available to date (Table 3, Figures 5 and 6) (Grierson and Long 1983).

Figure 5: Fir forest above 3,300m

The botanical exploration of Bhutan by foreigners was also reviewed by Grierson and Long (1983). The authors list 17 plant collectors who collected over 10,000 specimens between 1838 and 1980. Only a few of these expeditions were aimed purely at botanical and floristic studies.

The first recorded collections were made by Griffith in 1838 (Griffith 1939). Griffith was the medical doctor as well as the botanist of an English Mission which travelled to Bhutan in 1837-38. This mission, headed by Major Pemberton, entered Bhutan in the east to travel to Punakha to meet with the Bhutanese Government. Their trek of 640 km took them from Deothang, through Lhuentse, to Bumthang, Wangdue, Punakha, Thimphu, and Chhapcha. Griffith's travelogue includes many vegetation diagrams.

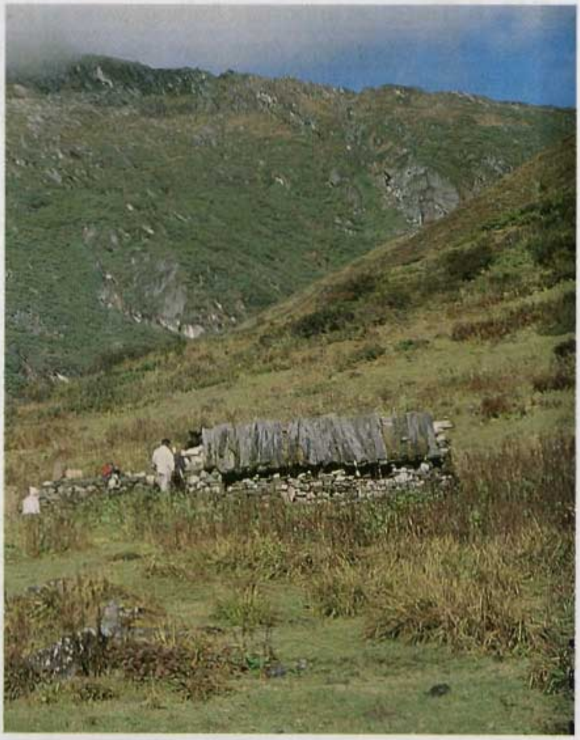

Figure 6: Alpine scrub

Descriptions of the vegetation in the Himalayas (Polunin and Stainton 1984; Stainton 1988; Stearn 1976) and in the Indian sub continent (Bor 1960) have been useful when studying Bhutanese vegetation. The collections of Ludlow and Sheriff (Stearn 1976) focused on primula and rhododendron species and are of special interest for studying the vegetation of alpine grazing lands in Bhutan.

A comprehensive description of the flora of Bhutan is being prepared by the Royal Botanical Gardens, Edinburgh and is well under way (Grierson and Long 1983, 1984, 1987, 1991; Noltie 1994, 2000, and additional volumes in progress). It provides an important base to describe grazing land plant communities and other fodder resources. The volumes containing the families *Cyperaceae* and *Juncaceae* (Noltie 1994), and *Poaceae* (Noltie 2000) are of particular importance.

Table 4: Contribution of different types of fodder resources to Bhutan's national fodder requirements

Fodder source	Relative contribution (%)	
Forest grazing	22	23
Natural grassland	22	38
Improved pasture	1	9
Shifting cultivation and fallow land	15	-
Fodder trees	20	15
Crop residues	20	13
Other	-	2
Source:	Roder 1990a	RGOB 1994

Fodder resources

The fodder resources used by livestock vary with the climate, the farming system, and the seasons. No reliable nation-wide data is available on the relative contribution of individual fodder resources but estimates agree that natural grazing lands, including forests, provide the highest proportion (Table 4).

The relative importance of the various fodder resources has been assessed recently in a survey carried out in selected geogs (sub-units of a dzongkhag) of Paro, Wangdue, Trongsa, Zhemgang, and Bumthang dzongkhags. The results are summarised in Table 5. The most important findings were as follow.

- With a few exceptions, there were only minor differences between fodder used by milking and non-milking animals. The main differences across all regions were that milking animals were more likely to be given residues from ara (local distilled alcohol) and chang (local beer) making.
- Forest grazing (including grazing on natural grasslands) was overall the most important fodder resource. The grazing of post-harvest crop fields, pangshing (grass fallow shifting cultivation land) and tsheri (bush fallow shifting cultivation land) areas, and common pasture were the next most important fodder resources.
- Depending on elevation and cropping systems, the most important winter feed was paddy straw, buckwheat straw *(Fagopyrum esculentum)*, and turnip.
- The post-harvest grazing of crop fields received the highest overall ranking as a source of winter feed.
- Residues from ara and chang making were given very high ratings in Bumthang and Trongsa during the summer and winter periods. In the other dzongkhags the rating for this source of fodder was low. This probably does not indicate a higher alcohol consumption in Bumthang and Trongsa, rather it is due to these residues being fed to pigs in the other dzongkhags, where there is a higher pig population.
- Fodder trees are not as important as generally thought. This may partly be due to the characteristics of the geogs included in the study, but even in a subtropical geog such as Drakten (Trongsa) the main winter fodder sources were ranked as firstly rice straw, followed by ara and chang residues, and then post-harvest grazing of crop fields, grazing tsheri, forest grazing, and only finally tree fodder.
- Fodder from improved pasture received a surprisingly high ranking, especially in Wangdue, Trongsa, and Paro dzongkhags. Similarly, hay as a fodder resource for winter feeding received high rankings from the cooler regions of Paro, Wangdue, and Bumthang. Perhaps the contribution from improved fodder has been underestimated in the past.

Fodder from registered grazing land

Bhutan has over 400,000 ha of registered grazing land (Table 6). These areas are known as tsadrog. The area of tsadrog available for large ruminants (cattle and yak) is about 1.6 ha per

Table 5: Rating of fodder resources for milking cattle						
Area details/ Fodder source	**Paro**	**Wangdue**	**Trongsa**	**Zhemgang**	**Bumthang**	**Average**
Geog and altitude[1]	Dobjari 2,400-4,000m Narja 2,300-4,000m	Sephu 3,000-4,000m Phubjikha 2,800-4,000m	Tangsibi 1,500-4,000m Drakten 1,200-3,800m	Trong 800-2,600 Nangkhor 600-4,000m	Tang 2,600-4,000m Chumey 2,600-4,000m	
Altitude range, district	2,000-4,000	1,000-4,000	800-4,000	200-4,000	2,600-4,000	
No. of households interviewed	152	172	146	130	133	
Summer period	**Proportion (%) of respondents listing a particular fodder[2]**					
Forest/natural grassland	43	26	45	47	88	50
Crop fields	2	2	45	52	81	37
Ara/chang residues	1	15	70	6	86	37
Pangshing and tsheri	3	43	45	1	73	33
Common pastures	27	37	25	38	18	29
Improved pastures	30	42	44	13	18	29
Other crop by-products	4	4	41	2	48	20
Cut and carry/weeds	58	0	0	0	0	12
Hay	1	24	1	0	2	6
Turnip and radish	0	9	1	1	0	2
Maize straw	3	<1	2	0	0	1
Fodder trees	0	2	0	0	3	1
Buckwheat[3] straw	1	1	0	0	0	1
Winter period						
Crop fields	0	1	84	51	83	44
Forest/natural grassland	3	11	41	47	87	38
Ara/chang residues	0	15	71	11	86	37
Turnip/radish	38	87	15	4	24	34
Hay/silo	33	64	9	0	63	34
Pangshing and tsheri	1	7	46	2	78	27
Rice straw	30	3	80	2	1	23
Buckwheat straw	6	16	5	0	87	23
Other crop by-products	1	10	36	4	51	20
Common pastures	1	3	20	41	15	16
Improved pastures	1	5	20	5	39	14
Fodder trees	15	8	33	3	8	13
Wheat and barley straw	24	0	0	0	0	5
Maize straw	1	0	8	0	14	5

[1] There is a considerable bias in this data towards higher elevation areas; [2] Respondents were asked to list their fodder resources and then rank them in sequence of importance. This table shows the proportion of respondents listing a particular fodder as first or second most important. The same ranking could be given to more than one fodder category; [3] *Fagopyrum esculentum*
Source: Roder, 1998b

Table 6: Grassland resources for individual dzongkhags

Dzongkhag	Tsadrog[1] ('000 ha)	Natural grassland[2] ('000 ha)	Area of tsadrog per animal[3] (ha)
Ha	67.4	12.1	5.63
Gasa	10.0	23.3	3.25
Thimphu	55.2	33.4	2.48
Paro	32.6	8.2	2.20
Trongsa	22.9	6.5	1.89
Bumthang	26.8	21.4	1.86
Punakha	18.4	1.9	1.78
Wangdue	38.8	14.2	1.56
Zhemgang	23.3	1.0	1.39
Trashigang	40.2	10.9	1.04
Samtse	15.4	0.1	0.95
Chhukha	26.2	3.0	0.94
Dagana	8.0	1.6	0.76
Lhuentse	7.5	9.5	0.46
S.Jongkhar	10.2	0.8	0.43
Mongar	7.8	1.4	0.27
Tashiyangtse	1.7	4.7	0.12
Pemagatshel	0.9	0.0	0.11
Sarpang	0.2	1.2	0.02
Tsirang	0.0	0.1	0.00
Total	**413.6**	**155.3**	**1.36**

[1] Registered grazing; [2] grassland estimated from aerial photos or satellite imagery; [3] area of tsadrog per number of cattle and yak combined
Source: LUPP 1995

animal. The natural grassland area estimated from aerial photographs is considerably lower than the official area of tsadrog, however. This is probably because in aerial photograph estimates a large part of the registered tsadrog was classified as forest as a result of the substantial tree cover in some tsadrog areas.

The most extensive areas of natural grassland are the areas of natural alpine grassland and scrubland found above the tree line at altitudes between 4,000m and 5,000m in the northern dzongkhags of Ha, Paro, Thimphu, Gasa, Wangdue, and Bumthang. Tsadrog is distributed somewhat differently (LUPP 1995). Dzongkhags with large areas of tsadrog include those with winter grazing areas under forest cover such as Zhemgang, Trashigang, and Chhukha. Relatively large areas of natural grassland can also be found at elevations between 700m and 2,100m in dry sites that were originally covered by chir pine forest.

Bhutan's natural (non-forested) grassland types were first discussed by Singh (1978), who described five types of grass cover (Table 7). Soon after, Dunbar (1979) published the first list of species and genera occurring in high altitude natural grasslands in Bhutan.

Vegetation composition and production

The following sources provide lists of species common in Bhutan: Griffith 1839; Karan 1967; Dunbar 1981; Dunbar 1985; Harris 1987; Numata 1987b; Tsuchida 1987; and Tsuchida 1991. The most exhaustive list describes the vegetation along the 640 km transect walked by Griffith (1839).

Most authors have been subjective in their descriptions and their observations have been influenced by seasonal trends in vegetation cover. Griffith (1839) travelled during the dry season (January to May) and his observations focus mostly on tree and shrub species. Others have also focused mainly on either tree species (Karan 1967) or grasses (Miller 1987a,b). Legumes, although present at most locations, are never mentioned in Miller's descriptions of grassland vegetation (1987a,b).

Interestingly, most reports are concerned with observations on Bhutan's alpine environments; there are only a few references for temperate and subtropical areas. In all ecological zones, there is virtually no quantitative data on the relative importance of species, their value as fodder, and their actual and potential dry matter yield.

Table 7: Natural grassland types and their dry matter yields, after Singh

Grassland type	Altitude (m)	Yield (t/ha)
Saccharum reed dominant cover	800-2,000	1.5-2.0
Chrysopogon-Themeda cover	2,500-2,800	1.0-2.0
Thin and short bamboo dominant cover	2500-3,000	data not available
High altitude scrub cover	above 2,800	data not available
Alpine and sub-alpine cover	3,500-5,000	0.3-0.4

Source: Singh (1978)

Numata (1987a) compared the natural grassland vegetation of Bhutan to that found in southwestern Japan. He described plant communities using the summed dominant ratio (SDR) of species based on the extent of their cover and height observed in quadrats. This method may, however, overestimate tall growing species. Tsuchida's 1987 and 1991 reports offer the most comprehensive descriptions of Bhutan's grassland communities, and the only source of information pertaining to Bhutan's subtropical areas; they are summarised in detail in Annex 1, Tables A1-A5. These tables provide average figures for between three and six sites from the data provided by Tsuchida. Based on his observations, Tsuchida delineated grassland types depending on elevation and precipitation (Table 8).

Table 8: Natural grassland types and dominant species in Central and Western Bhutan according to Tsuchida

Altitude (m)	Dry soils	Moist soils	Wet soils
1500–2,500	**Chrysopogon grassland** *Chrysopogon aciculatus* *Heteropogon contortus* *Eragrostis tenella* *Ischaemum rugosum*	**Cynodon grassland** *Cynodon dactylon* *Digitaria setigera* *Digitaria stricta* *Digitaria spp* *Chrysopogon aciculatus*	**Paspalum grassland** *Paspalum scrobiculatum* *Fimbristylis spp* *Pycreus spp* *Eleusine indica*
2,500–3,500	**Agrostis grassland** *Agrostis nervosa* *Eragrostis nigra* *Festuca sp*	**Arundinella grassland** *Arundinella hookeri* *Eragrostis nigra* *Agrostis pilosula*	**Carex grassland** *Carex nubigena* *Juncus sp* *Fimbristylis spp* *Eriocaulon sp* *Luzula* sp Kobresia duthiei
3,500–4,000	**Festuca grassland** *Festuca ovina* *Festuca spp* *Anaphalis triplinervis*	**Agrostis grassland** *Agrostis inaequiglumis* *Carex nubigena* *Agrostis pilosula* *Poa sp*	**Carex grassland** *Carex nubigena* *Juncus sp* *Kobresia duthiei*
4,000–5,000	**Festuca grassland** *Festuca sp*	**Kobresia grassland** *Kobresia duthiei* *Poa sp* *Potentilla microphylla* *Deyeuxia pulchella*	**Juncus grassland** *Juncus* sp

Source: Tsuchida 1991

Tables 9 and 10 provide summaries of the natural grassland communities that have been described by various authors. No information is available on the relative importance of these communities. At elevations below the tree line, grassland communities generally consist of secondary vegetation, strongly influenced by cultivation, fire, and grazing (Figures 7 and 8).

Figure 7: Sheep grazing on permanent grassland at 3,000m

Figure 8: Yak grazing bamboo (*Yushania microphylla*) dominated winter pasture (3,100m)

Dry sites ranging from 700 to 2,100m altitude are frequently dominated by *Cymbopogon* type grassland (Miller 1989a) (Figure 9, Table 9). Major grass species at these sites include *Cymbopogon khasianus, Cymbopogon gryllus, Cymbopogon* sp, *Apluda mutica, Arundinella nepalensis,* and *Heteropogon contortus.* Above these elevations *Themeda* sp, *Schizachyrium delavayi,* and *Eragrostis* spp become dominant (Roder 1983c; Roder et al. 1997b). At a typical grassland site evolving from shifting cultivation in Bumthang at 2,700m altitude, *Schizachyrium delavayi* was found to contribute over 60% of total dry matter yield (Figure 10, Table 11) (Roder 1983b and 1990a).

Figure 9: Grassland dominated by *Cymbopogon* species in the *Pinus roxhburgii* belt, Wangdue valley

Table 9: Natural grassland communities described by various authors				
Region	**Site description**	**Elevation**	**Reference**	**Genera/Species**
Humid/Dry Sub-tropical (<1,000m) to Warm Temperate (1,000-2,400m)				
Chapcha	Grassy banks	2,400	Griffith 1839	*Agrostis, Bromus, Ervum, Aster, Rumex, Hieraciae, Lactuca, Astragalus, Vicia*
Eastern Bhutan	Dry sites	700-2,100	Miller 1989a	*Cymbopogon khasianus, Cymbopogon sp, Apluda mutica, Arundinella nepalensis, Chrysopogon gryllus, Heteropogon contortus*
Cool temperate (2,500–3,800m)				
Nikkachu	Pasture	2,530	Numata 1987a	*Senecio chrysanthemoides, Arthraxon sikkimensis, Paspalum commersoni, Pteridium aquilinum, Arundinaria sp, Elymus sikkimensis, Rosa sericea, Potentilla griffithii, Digitaria ciliaris, Persicaria nepalensis, Poa annua, Geranium nepalense, Commelina paludora, Anaphalis triplinervis, Amaranthus viridis, Artemisia indica, Eleocharis congesta, Bulbostylis densa, Plantago erosa*
Chapcha	Meadow	2,700	Griffith 1839	*Baptisia, Gnaphalium, Pedicularis, Rosa, Bistorta, Nepenthes, Cephalotus, Pteridium*
Bumthang	Evolved from shifting cultivation	2,650	Roder 1983b	*Schizachyrium delavayi, Eragrostis nigra, Potentilla* sp, *Agrimonia* sp, *Lespedeza sp, Desmodium sp*
Merak-Sakten	Dry south–facing slopes	2,500-3,000	Miller 1989a	*Schizachyrium delavay, Arundinella hookeri, Helictotrichon virescens, Themeda quadrivalvis, Bromus ramosus*
Merak-Sakten	Forest meadow (oak-rhododendron forest)	2,900-3,300	Miller 1989a	*Eragrostis nigra, Arundinella hookeri, Agrostis sp, Sedges, Geum elatum*
Merak-Sakten	Moist bamboo grassland sites	3,200-3,600	Miller 1989a	*Bambusa sp, Dactylis glomerata, Helictotrichon virescens, Agrostis sp, Bromus ramosus, Brachypodium sylvaticum*
Merak-Sakten	Drier south–facing slopes	3,000-3,800	Miller 1989a	*Danthonia cumminsii*

Table 10: Vegetation components listed for alpine regions[1]

	Lingshi	Lunanana				Merak-Sakten		Kidiphu	Western Bhutan		
		Meadow	Dry scrub	Moist scrub	Scree slopes	Fir forest	Grassland	Grassland	Winter pasture	Spring pasture	Summer pasture
Altitude (m)	3,600-4,900	3,700-5,000	3,700-4,200	3,800-4,500	4,800-5,500	3,600-3,900	3,900-4,100	4,000-4,100	3,400-4,100	4,100-4,600	4,200-4,800
References[2]	1	2	2	2	2	3	3	4	5	5	5
Carex	X		x	x	x	x	x		x	x	x
Agrostis	X	x	x		x	x	x		x		x
Festuca	X	x	x			x	x	x			x
Poa	x	x		x	x	x	x	x			
Rhododendron	x		x	x				x	x	x	x
Potentilla	x		x	x				x		x	x
Primula	x	x	x	x				x			
Danthonia	x	x	x	x						x	
Stipa	x	x	x	x							
Junceacea			x						x	x	x
Bromus	x						x		x		
Gentiana		x			x						x
Cotoneaster	x		x							x	
Delphinium	x	x			x						
Rheum	x	x		x							
Salix				x				x	x		
Elymnus			x	x							
Koeleria	x							x			
Deyeuxia	x							x			
Trisetum	x					x					
Anemone			x						x		
Anaphalis										x	
Sausaria				x	x						
Geranium	x									x	
Berberis	x								x		
Juniperus	x		x								
Bryophyta									x		x
Polygonum			x					x			
Calthus			x	x							

[1] Genus only included if listed more than once in a reference; [2] references 1 – Dunbar 1979, 2 – Gyamtsho 1996, 3 – Miller 1989a, 4 – Roder 1983b, 5 – Harris 1987

Figure 10: *Schizachyrium delavayi* dominated grassland in Bumthang (2,800m)

Table 11: Composition of grassland evolving after shifting cultivation (Bumthang, 2,700m)

Species	Botanical composition (%)[1]
Schizachyrium delavayi	64
Eragrostis nigra and other grasses	19
Potentilla sp	12
Lespedeza sp, *Desmodium* sp, and others	5

[1] Dry matter yield was 0.8 t ha^{-1} year^{-1}
Source: Roder 1990a

The most important genera at higher elevations in Bhutan include *Carex, Agrostis, Festuca, Poa, Rhododendron, Potentilla, Primula,* and *Danthonia* (Figures 11 and 12, Table 10). The lower elevation grass species which other authors have noted as dominant, such as *Cymbopogon, Apluda* and *Themeda* species and *Schizachyrium delavayi* (Miller 1989a; Roder 1983b; Roder et al. 1997b) were not recorded by Tsuchida (1987, 1991).

Legume species with a wide distribution in natural grassland communities include *Astragalus leucocephalus, A. bothanensis,* other *Astragalus* spp, *Desmodium* spp *Gueldenstadtia himalaica, Hedysarum* spp, *Indigofera* spp, *Lespedeza* spp. *Parochetus communis,* and *Vicia tibetica* (Roder 1982c; Grierson and Long 1983; Grierson and Long 1984; Polunin and Stainton 1984; Gyamtsho 1996).

Natural grassland cover at higher elevations has been assessed by measuring plant cover (Dunbar 1979; Harris 1987). Cover provides an indirect indication of (1) the

Figure 11: Vegetation cover dominated by *Carex* species, Kidiphu (4,000m).

Figure 12: Sheep grazing on alpine pasture (4,000m)

relative importance of individual species, (2) the relative and actual yield of individual species and plant communities, (3) grazing effects, (4) the health of plant cover, and (5) the levels of soil and moisture conservation by different kinds of plant cover. Dunbar (1979) reported the cover on a south-facing slope as 41% plant cover, 13% litter cover, and 46% bare soil. Harris (1987) reported that the amount of bare ground was greater in heavily grazed areas.

No reliable data has been gathered on natural grassland production under herder or farmer management. Several observers have estimated production based on visual observations (Singh 1978; Harris 1987; Rumball 1988a; Miller 1989a; Gyamtsho 1996), whilst others have physically measured the dry matter production of areas from where grazing animals have been excluded (Dorji and Roder 1980; Roder 1983) (Figure 13, Table 12). In these estimates the dry matter yields ranged from 0.7 to 3.0t ha^{-1} for temperate grasslands at elevations of less than 3,000m and 0.3 to 3.5t ha^{-1} for alpine grasslands at elevations over 3,000m. Estimates based on actual measurements (Gyamtsho 1996; Roder 1983) are generally lower than those based solely on visual assessments (Harris 1987; Miller 1989a). Dorjee (1986) estimated an average carrying capacity of 0.5 livestock units per hectare for subtropical regions, 0.25 livestock units per hectare for temperate regions, and 0.10 livestock units per hectare in alpine regions. With a dry matter requirement of 8 kg per animal per day, this would correspond to annual dry matter yields of 1.5t ha^{-1} in subtropical regions, 0.73t ha^{-1} in temperate regions, and 0.29t ha^{-1} for alpine regions. If an average dry matter production of 0.7t ha^{-1} is assumed, then Bhutan's registered grasslands produce about 289,000 tonnes of dry matter every year, sufficient to

Table 12: Estimates of natural grassland production and quality

Source & method	Description, management	Elevation	Dry matter (t ha^{-1} $year^{-1}$)
Singh (1978), visual[1]	*Saccharum* and reed dominant	800–2,000	1.5–2.0
	Chrysopogon/Themeda cover	2,500–2,800	1.0–2.0
	Alpine pasture	3,500–5,000	0.3–0.4
Harris (1987), visual[1]	Winter yak pasture	3,400–4,100	1.5–3.5
	Spring/autumn yak pasture	4,100–4,600	2.5–3.5
	Summer yak pasture	4,200–4,800	0.5–1.8
Miller (1989a), visual [1]	Dry south–facing slopes	2,500–3,000	2.0–3.0
	Forest meadows	2,900–3,300	0.8–1.0
	Dry south–facing slopes	3,000–3,800	1.0–1.5
	Forest meadow in fir belt	3,600–3,900	1.0
	Bamboo grassland, moist	3,200–3,600	2.0–3.0
	Alpine rangeland	3,900–4,500	0.5–1.0
Gyamtsho (1996), disk method[1,2]	Natural grassland	<4,000	0.3
		4,000–4,500	0.4
		>4,500	0.5
Dorji and Roder (1980), clipping[3]	Bamboo	2,700	1.0
Roder (1983), clipping[4]	Natural grassland	3,900–4,000	0.4 (0.2–0.7)
Roder (1983), clipping[4]	Natural grassland	2,700	0.7

[1] Estimates/measurements made at one point in time, heavily biased by previous grazing treatment; [2] the herbage disk meter consists of a vertical graduated axis, a collar, and a linked aluminium disk that settles on the herbage, the disk height from the ground is used as an indicator of the standing dry matter (Gyamthso 1996); [3] grazing animals excluded and yield measured by repeated cutting over one season; [4] grazing animals excluded and yield measured by repeated cutting (simulating grazing animals) over three seasons.

feed about 99,000 livestock units (8 kg dry matter per day), or 30% of the livestock population.

Natural grassland management and herding systems

Traditional production systems take advantage of the variations in climate and vegetation as herders migrate with their animals according to the seasons. High altitude pastures are grazed during the summer, whilst lower elevations (usually in the south) are used for winter grazing (Table 13, Figure 14).

Figure 13: Cages used in measuring grassland production

Overgrazing is frequently mentioned as the main cause of low and deteriorating grassland yields (Fischer 1971; Miller 1986) and as a threat to the environment (NES 1992). No information is available on livestock numbers and grazing pressure prior to 1960. It is assumed that the periodic occurrence of epidemics would have reduced the human and livestock populations from time to time thus reducing the pressure on fodder resources (Fischer 1971). The last major outbreak of the cattle disease rinderpest in the late 1960s substantially reduced livestock numbers (Fischer 1971; Maurer 1985).

Table 13: Cattle migration from Bumthang (south during winter)

Geogs	Migration as proportion of the total	
	Households (%)	Animals (%)
Choekor	6	12
Tang	9	17
Chumey	41	51
Ura	59	67

Source: Baumgartner 1984

Herding systems are influenced by the natural environment and the socioeconomic setting (Gyamtsho 1996). Households with small herds often pool their animals. Transhumance yak herding systems have been described for Merak Sakteng (Gyamtsho 1996; Miller 1987b; Wangmo 1984), Soi Naro (Gibson 1991), and Laya (Gyamtsho 1996). Most herders have grazing rights to one or more areas of pasture either individually or as part of a community. In some regions large areas of grazing land are owned by absentee landlords (Gibson 1991; Gyamtsho 1992). While most herders and absentee owners treat their grasslands as their family's inheritance, the 1991 Land Act states that all grazing land belongs to the state and herders only have the grazing rights.

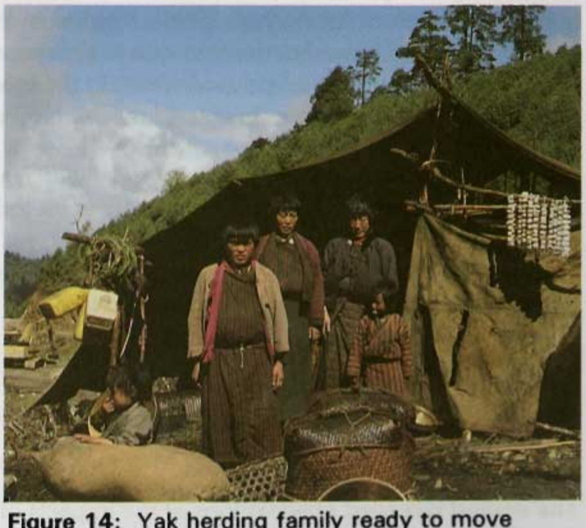

Figure 14: Yak herding family ready to move camp (Yutongla, 3,700m)

A system to allot communal pastures to herders has been described for Ha (Ura 1993). In other areas, it is reported that community pastures are grazed indiscriminately on a free-for-all basis (Dorjee 1993; Gyamtsho 1996).

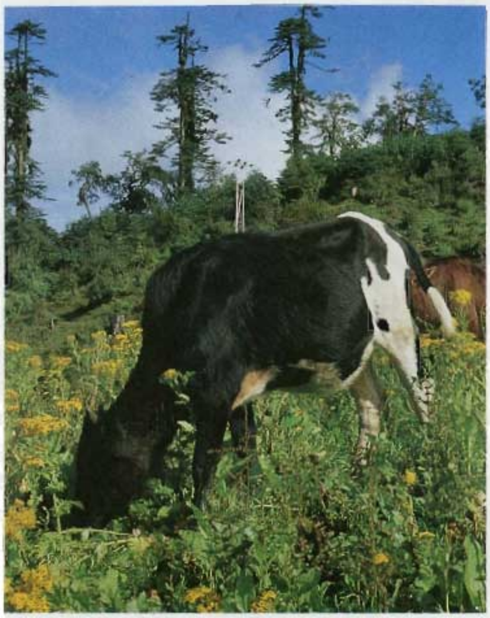

Figure 15: Cow grazing grassland dominated by *Senecio* sp

Pastures at elevations of between 2,000m and 3,000m are often used by cattle for summer grazing and by yak for winter grazing (Gyamtsho 1996). It is not uncommon for two parties, such as a transhumance yak herder and a family from a nearby settlement, to have the grazing rights over the same area. These situations inevitably put extra pressure on the grasslands.

Forest and natural grassland communities include poisonous plant species such as *Aconitum sp*, *Senecio* sp (Figure 15), *Euphorbia* sp, *Pteridium* sp, and *Eupatorium adenophorum* (Gierson and Long 1984; Gierson and Long 1987; Winter et al. 1992; Denzler et al. 1993; Winter et al. 1994a; Winter et al. 1994b; Gyamtsho 1996; RNR-RC Jakar 1997d). Livestock will not graze these species except under abnormal circumstances such as lack of other feed sources, exhaustion as a result of long travelling distances with heavy loads, or in other stress situations.

Wildlife interactions

Natural grassland resources support a wide range of wild animals of which the takin *(Budorcus taxicolor)*, the blue sheep (*Pseudovis nayaur*), the sambar (*Cervus unicolor*) and the musk deer *(Moschus chrysogaster)* are the most important. In recent years some of these species, especially the blue sheep, have increased, probably due to a decline in the population of its predators (Wangchuk 1994). Herders in the Laya region have claimed that the grazing resources have deteriorated due to an increase in the number of blue sheep (Gyamtsho 1996). This is likely, considering the erosion damage at grazing sites where yak are joined by flocks of blue sheep and marmots (Gyamtsho 1996).

Another wildlife species that has substantially increased its population is the wild boar. Wild boar damage is often cited as a major constraint to fodder development, due to its burrowing for roots (RNR-RC Jakar 1996c; Wangdi 1992).

Forest grazing

Herbaceous undergrowth in forested areas is an important direct source of ruminant fodder and indirectly of plant nutrients (manure). The majority of respondents in a recent survey (Roder et al. 1998b) considered forest grazing as the main source of ruminant feed, especially during the summer period (Table 5, Figure 16).

The earliest recorded observations of the impacts of forest grazing were made by White (1909), during a trek he made in the Ha and Paro valleys.

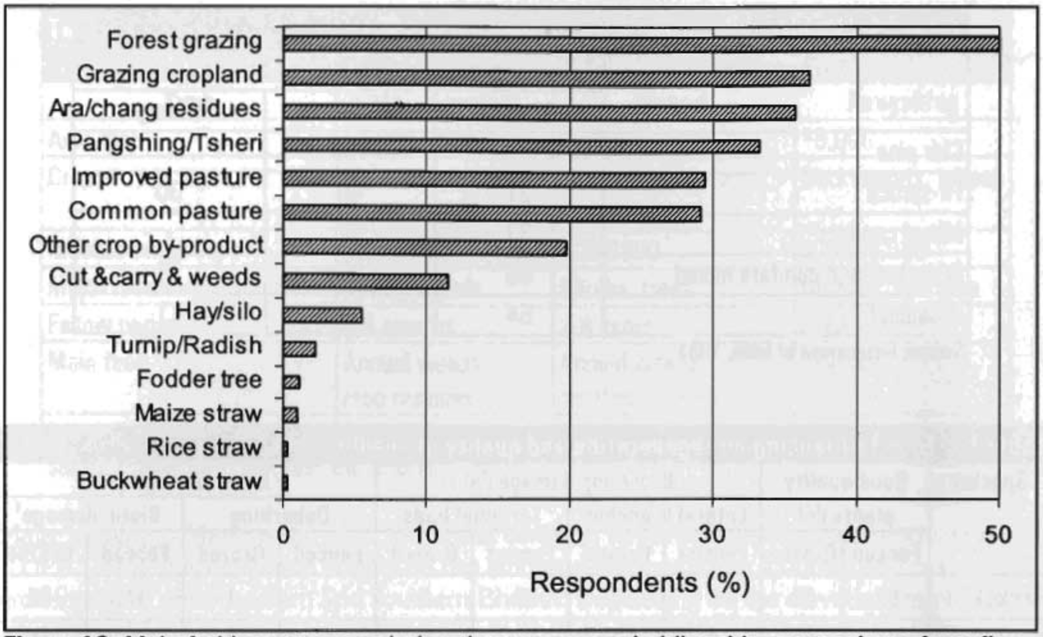

Figure 16: Main fodder resources during the summer period listed by respondents from five dzongkhags

> "On either side and at our back was a deep fringe of fine trees of every age, from the patriarch of the forest down to young seedlings. The Bhutanese seem to have acquired the secret of combining forest self-reproduction with unlimited grazing for, from the time we left Rinchengong (Ha dzongkhag), we passed through forests which, without exception, were self-reproducing."

Tegbaru (1991) has reviewed forest grazing in Bhutan. The assessment by forest specialists today is far less positive than that of White. The widespread grazing of animals in forest systems is frequently blamed for forest degradation or destruction. It has become routine to blame the practice of forest grazing for poor forest regeneration (Blower 1989; Tegbaru 1991; NES 1992; Sangay 1997) and poor forest condition. Yet, there is no quantitative information to prove that livestock grazing in forests prevents forest regeneration or harms forest health. The limited studies that have attempted to quantify livestock effects on forests have either concluded that livestock grazing is not a major problem for forest regeneration and health (Gibson 1991; RNR-RC Jakar 1997b; Tegbaru 1991), or that further studies are required to understand its impact (RGOB/ISDP 1995). A recent assessment of forest grazing in Zhemgang dzongkhag concluded that forest grazing can be an efficient use of available resources (RGOB/ISDP 1995).

Country-wide estimates in the 1970s indicate that grazing was either moderate or absent from most areas of southern Bhutan (Table 14). A recent study of coniferous forests in Bumthang concluded that browsing damage due to grazing animals is negligible for coniferous species, although broadleaved deciduous tree species exhibit more damage (Table 15) (RNR-RC Jakar 1997b).

While forest grazing may not have serious effects on the regeneration and health of well-managed forests, it is a serious problem in forest ecosystems that have been disturbed by mechanical logging or by poor silvicultural management. These effects may be especially harmful in subtropical broadleaf forests.

Table 14: Incidence of forest grazing reported in 1981			
Forest type	Grazing incidence (% of forest area)		
	Absent	Moderate	Heavy
Chir pine	-	100	-
Fir-spruce	21	49	30
Mixed conifers	33	67	-
Broadleaf and conifers mixed	55	30	15
Broadleaf	54	34	11

Source: Government of India, 1981

Table 15: Effect of fencing on regeneration and quality of seedlings										
Species	Good quality plants (%)		Browsing damage (%)				Other damage (%)			
			Lateral branches		Terminal buds		Debarking		Biotic damage[1]	
	Fenced	Grazed	Fenced	Grazed	Fenced	Grazed	Fenced	Grazed	Fenced	Grazed
Hemlock	82	68	0	0	0	1	7	1	11	30
Fir	91	85	0	0	0	0	0	0	9	15
Blue pine	77	91	0	0	0	0	8	0	15	9
Rhododen-dron	90	84	1	0	0	0	0	0	10	16
Birch	78	57	0	20	0	6	0	0	22	17
Other broadleaves	59	46	0	3	0	4	2	0	39	48

[1] Damage by rodents

Source: RNR-RC Jakar 1997b

Forest grazing and the use of forest litter leads to the constant transfer of nutrients from the forests to the cropped areas (Roder 1990b). Depending on the level of mineralisation of nutrients from the parent material this may lead to a gradual depletion of nutrients in some forest ecosystems.

Fallow land

As soon as crops are harvested, cattle are allowed to graze freely in the crop fields. The quantity and quality of available fodder will vary substantially depending on the crop, the weed flora, and the harvesting systems used (Table 16). The grazing period varies with the crop and the type of cropping system, but it is generally extensive during the dry winter season. During winter periods the grazing of fallow lying crop fields was the most frequently cited fodder resource in Roder's survey (Roder 1998b, Table 5).

Fallow systems which provide substantial quantities of fodder include the seasonal fallows in maize systems, which extend from two to eight months, and the long term fallows of two to twenty years in the pangshing and tsheri shifting cultivation systems. There are no quantitative data available on the dry matter production and quality of these systems. Table 16 shows a qualitative description of the most important systems.

Table 16: Fodder from fallow land and selected characteristics of the major crop and fallow systems			
Type	**Maize system**	**Tsheri**	**Pangshing**
Area (ha)	55,000	40,000	10,000
Crops	Maize	Maize, millets, rice, buckwheats	Buckwheats, wheat
Altitude range (m)	300-2,600	300-2500	2,500-4,000
Major fallow vegetation	Annual weeds	Shrubs, trees	Grasses, blue pine
Fallow period	4-8 months	2-8 years	6-20 years
Main feed	Annual weeds, crop residues	Annual weeds, shrubby species	Grasses
Dry matter (t/ha)	0.1-1.0	0.2-3.0	0.1-1.5

Source: Adapted from LUPP 1995 and Roder et al. 1992a

Maize systems – Maize is the most important cereal in terms of both area and production (LUPP 1995). It is cultivated mostly on dry land at elevations up to 3,000m. The main maize growing areas are in eastern and southern Bhutan. Depending on the elevation, rainfall and levels of soil fertility, maize is usually grown in combination with a variety of other crops in intercropping and sequential cropping systems (Table 17) (Roder and Gurung 1990). The length of the fallow period and the amount of fodder available are also dependant on the same factors and the associated other crops. Livestock are generally allowed to graze the fields immediately after the harvesting of maize cobs.

The maize stems are often harvested and stored for winter feed. The large extent of maize cultivation means that a substantial quantity of crop residue is available for fodder.

Table 17: Typical maize growing systems in Bhutan		
System	**Importance (% of total maize area)**	**Altitude (m)**
Maize-maize (often intercropped with beans, soybeans, or *Vigna* sp)	20	<1,000
Maize-paddy	<5	<1,000
Maize-wheat or barley	25	900-2,000
Maize-buckwheat	10	900-2,400
Maize (often intercropped with beans, soybeans, or *Vigna* sp)	30	1,500-3,000
Maize intercropped with potato	<5	1,500-,700

Source: Roder and Gurung 1990

Slash and burn bush fallow (tsheri) system – This system is found in many subtropical and tropical regions of Asia (Roder et al. 1992a). The vegetation - consisting of trees, shrubs, other perennials and annuals - is cut during the dry season, allowed to dry, and burned shortly before seeding the crop seed. Seeds are either dibbled or broadcast. The crops are mainly maize, millet, rice, and buckwheat (Figure 17).

Grass fallow (pangshing) system – This is a fallow vegetation type that evolves several years after abandonment of cropping and persists under grazing. It consists of short grasses, sedges, and forbes, and is often interspersed with blue pine trees (*Pinus wallichiana*) in the cool temperate zone. Prior to cultivation, the top soil layer is cut to about 5-7 cm depth with a hoe and left to dry for several months. The dry top soil is collected in conical mounds spaced 2 to 3m apart, with between 1,200 and 2,500 mounds per hectare (Figure 18). Small quantities of blue pine needles or dry manure are then added to each mound as fuel. This fuel is ignited and the organic material in the dry soil mounds burn slowly, eventually reaching temperatures of 500°C or higher (Roder et al. 1992a, 1993a). This burning lasts for several hours and results in significant losses of organic matter and nitrogen. As all the vegetation is burnt off, the soil is left fully exposed to the forces of erosion. Buckwheat seeds broadcast in April are sometimes incorporated into the soil using a traditional bullock drawn plough or manually with a rake. Labour inputs are high at between 150 and 400 person days per hectare. Most of the labour (65-85%) is required for land preparation. No weeding is necessary.

Figure 17: Different stages of fallow vegetation in the tsheri (Bush fallow) shifting cultivation system

Other cropping systems – Fallow land from other kinds of cropping systems, although locally important, contribute little to the overall production of fodder. Wheat and barley are only grown over a limited area in Bhutan and have short fallow periods. Fallow fields of wheat, barley, and buckwheat are important at higher elevations, while rice fallow provides some grazing at elevations below 2,500m.

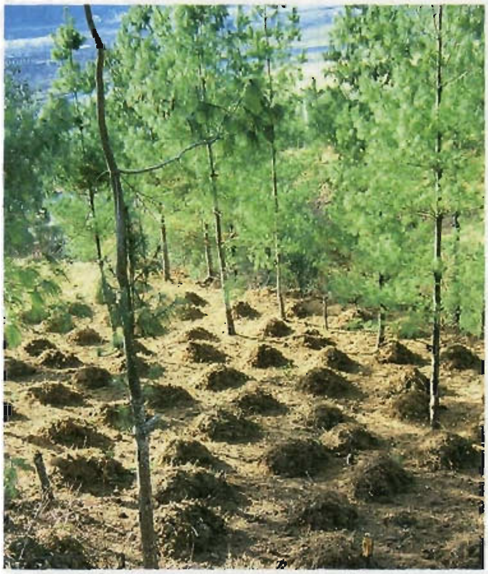

Figure 18: Mounds prepared with dry topsoil and ignited with additional fuel in the pangshing (grass fallow) shifting cultivation system

Crop residues

The contribution of crop residues to Bhutan's total livestock feed requirements has been estimated at 13% by RGOB (undated), 20% by Roder (1982c), and 43% by Verma (1984). The use of crop residues varies with the season, livestock type, and region. Verma (1984) estimated Bhutan's annual straw production at 378,000t of which 232,000t is used for livestock feed. This was probably an overestimation.

Rice, maize, and sweet buckwheat stems are an important source of winter feed in many areas (Figures 19 and 20). Rice straw is used as a winter livestock feed by almost all farmers who grow rice (Tables 5 and 18). Maize residues are the main winter feed in the major maize growing areas. Sweet buckwheat is mainly cultivated at higher elevations for the production of winter feed. In a survey of 206 households in Bumthang dzongkhag, 24% of households indicated production of winter feed from stems as the primary reason and 59% as the secondary reason for growing sweet buckwheat (RNR-RC Jakar 1996b). Other important crop residues include inferior and broken grain, husks and other chaff, residues from chang and ara making, and by-products from milling grain.

Arable fodder (annual species grown on cropland)

Throughout Bhutan, farmers traditionally produce small quantities of arable fodder for use during the dry season. These are mainly fed to draft animals whilst they undertake field preparation work at the beginning of the rainy season. With a gradual increase in the milk production potential of crossbred cows, these fodders are also becoming an important source of feed for lactating cows. The most important species are turnip, radish, pumpkin, maize, wheat, barley, and oats.

Figure 19: A store with maize husks for winter feed

Turnip, radish, and pumpkin are the most important arable fodders at elevations between 2,500m and 4,000m. They are fed to milking cows, growing animals, draught animals and pigs throughout the winter season, especially when the grasslands are covered with snow. At higher elevations individual households may cultivate up to 0.3 ha of turnip annually. In a survey of Sephu and Phubjikha geogs (Wangdue dzongkhag), 87% of households said that turnip was a major fodder resource during the winter (Table 5) (Roder 1998b). Turnips are traditionally important. Samuel Turner (1800) made the following observations:

> "The turnips peculiar to this country, deserve a decided preference over all those that I have ever seen. They are large, free from fibres, and remarkably sweet; and it is with justice, that the inhabitants pride themselves on their great superiority".

Figure 20: Buckwheat *(Fagopyrum esculentum)* straw stored for winter feed

Maize is cultivated to feed draught animals in May and June in lower areas such as Zhemgang and Sarpang. Wheat and barley are cultivated over a wide range of production systems including the rice systems of Paro and Thimphu and the wheat/barley systems found at higher

Table 18: The quantity and quality of major crop residues				
	Maize	**Rice**	**Buckwheat**	**Wheat**
Production (References 1 & 2)				
Area ('000 ha of particular crop)	55.5	45.1	7.3	9.6
DM produced ('000 t)	110	90	7	10
DM used as fodder ('000 t)	50	80	3	2
Relative importance in area of production[2]				
Households (%)	95	94	90	30
Reference[1]	2	3	3, 4	2
Quality of feed				
Crude protein	6.1	4.4	5.7	4.2
Crude fibre	29.1	39.2	42.8	41.1
Reference[1]	3	5	3	5

[1] References 1 – MOA 1997a (for area estimates); 2 – estimates by authors of review; 3 – RNR-RC Jakar 1996b; 4 – RNR-RC Jakar 1997a; 5 – Tamang 1987; [2] Proportion of households using the particular crop residue

elevations in Wangdue and Trongsa dzongkhags. Oats have partly replaced wheat and barley as winter fodder in the rice growing areas of Paro, Thimphu, Wangdue, and Trongsa.

Tree fodder

In many parts of Bhutan, tree fodders are an important source of feed for ruminant livestock during the dry winter season (Figures 21 and 22). The estimated contribution of 19-20% (RGOB undated; Roder 1982c) to the overall fodder needs of the ruminant population is probably an overestimate. A survey carried out in 1982 found that a large variety of tree species were used as fodder (Roder 1985). The species used, their relative importance, and the management practices vary according to the altitude, the availability of other types of fodder, and the prevalent land use practices.

A recent survey (Tshering et al. 1997a, Table 19) found that 100% of households in Chhukha, Trongsa, and Mongar dzongkhags, and the majority of households in Punakha, Wangdue,

Figure 21: Tree fodder species along the borders of paddy fields, Samchi (300m)

Figure 22: Calf feeding on leaves of tree fodder

Zhemgang, and Lhuentse dzongkhags, had fodder trees. The number of trees owned by individual households ranged from 1 to 1,015. The importance of tree fodder tends to increase with decreasing elevation. The highest numbers of fodder trees were found in Zhemgang and Chhukha dzongkhags. Most households said that they wanted to plant additional trees.

Table 19: The extent of fodder trees in seven dzongkhags

Dzongkhag	Altitude range	Sample (no of hhs)[1]	HHs with trees (%)	Species (no.) Per hh Av	Species (no.) Per hh Range	Species (no.) Per dzongkhag	Trees owned (no./hh) Av.	Trees owned (no./hh) Range
Punakha	1,700-2,400	254	76	<2	1-3	14	5	1-94
Wangdue	1,220-2,000	248	79	2	1-6	5	6	1-56
Trongsa	800-4,400	48	100	2	1-4	4	12	2-35
Chhukha	320-1780	263	100	5	1-13	28	53	1-1015
Zhemgang	160-2,000	54	94	2	1-5	10	17	1-70
Lhuentse	2,000-5,000	21	95	2	1-3	2	8	2-22
Mongar	650-3,700	18	100	1	1	2	12	2-40

[1] hh - household

Source: Tshering et al. 1997

The number of species reported ranged from 28 in Chhukha to only 2 in Lhuentse and Mongar dzongkhags. The largest number of species used was also in Chhukha dzongkhag. *Ficus roxburghii* was the most important species in all dzongkhags with *Ficus cunia* as the second most important.

At elevations above 2,000m, the choice of tree fodder species is limited (Roder 1992). The most important higher elevation species are willow *(Salix babylonica)* and evergreen oak *(Quercus semecarpifolia)* (Roder 1992) (Figure 23). Willow, although an excellent fodder, has the disadvantage of shedding its leaves at the beginning of the dry winter season.

Fodder trees are mainly found near to houses, along fences, and along field boundaries (Table 20). Future plantings of trees will most likely be along cropland borders and in separate fields.

There are no area based yield data available for tree fodder in Bhutan. Yields for temperate species extrapolated from single tree measurements have been estimated at 4t ha^{-1} $year^{1}$ for willow, 2t ha^{-1} $year^{1}$ for evergreen oak, 4t ha^{-1} $year^{1}$ *for Populus robusta*, and 12t ha^{-1} $year^{1}$ for Chinese pear (Roder 1992).

Figure 23: Cow feeding on *Quercus semecarpifolia* leaves

Table 20: Indigenous preference for fodder tree location: Response to the question "Where are the trees planted"

Where planted?	Per cent of respondents						
	Punakha	Wangdue	Trongsa	Zhemgang	Chhukha	Lhuentse	Mongar
Near houses	47	62	35	43	41	33	50
Along fences	11	2	0	22	3	29	22
Crop field boundaries	7	9	56	20	43	52	28
Inside crop fields	1	6	4	11	27	0	0
Separate field	2	2	4	7	13	0	0

Source: Tshering et al. 1997

Most tree fodders are inferior in quality to herbaceous species (Tamang 1987). Willow is an exception as it has excellent nutritional qualities and high palatability (Roder 1992; Wangdi et al. 1997). All farmers viewed *Ficus roxburghii* as giving superior dry matter yield (Table 21) and being a comparatively good quality fodder (Tshering et al. 1997a). The nutritional qualities of tree fodder are discussed in detail in Chapter 3.

Table 21: Fodder tree yield estimate (in loads per tree)

Species	Sample size (household no.)	Yield[1] (no. of loads)	Standard deviation[2]
Ficus roxburghii	138	5	4.7
Artocarpus lakoocha	18	3	1.6
Gmelina arborea	52	2.8	1.6
Ficus cunia	83	2.7	1.4
Litsea monopetala	27	2.7	1.6
Sterosperum sp	56	2.4	1.4
Saurauia nepaulensis	37	2	1.2
Bauhinia purpurea	63	2	1.2
Brassaiopsis hainla	29	1.9	0.8
Ficus nemoralis	26	1.7	1.1

[1] Load of approximately 40 kg; [2]Variation in reported yield

Source: Tshering et al. 1997

Fodder conservation - winter feed

Fodder availability from permanent grasslands peaks in the wet summer months, with a deficit in the dry winter period (Roder 1998c). The post-harvest grazing of cropland, forest grazing, residues from alcohol production, hay, and root crops are the main sources of winter fodder (Figure 24, Table 5). Farmers and herders have developed a number of methods to extend the availability of fodder over the entire year. These include:

- deferred grazing of permanent grasslands (Harris 1987);
- use of tree fodder species which have green foliage during the dry season (Roder 1992, Tshering et al. 1997a; and
- seasonal migration to lower areas (Figure 25).

Deferred grazing of permanent grasslands and migration are suitable for large cattle herds but generally not feasible for smallholders. Tree fodders are mostly used by smallholders on their privately owned land, and by migrating cattle herds in the forests.

Except for the evergreen oak, neither evergreen nor deciduous tree fodders are available at elevations above 2,500m and so livestock owners in these regions have to find other alternatives. Hay made in small fenced-in areas (tsa dham) has been the traditional means of fodder

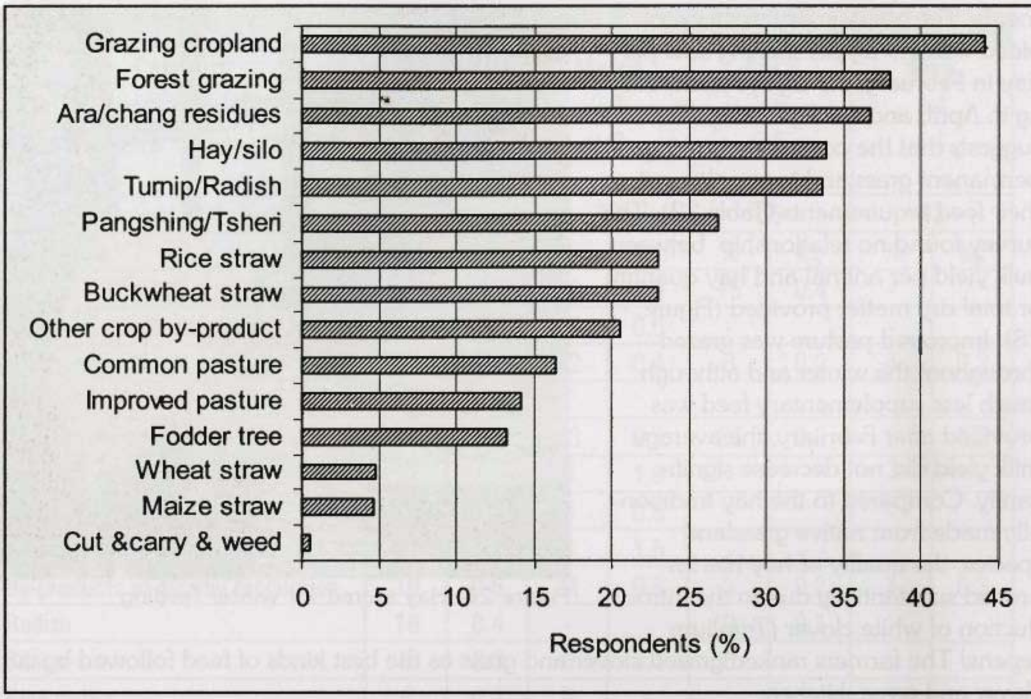

Figure 24: Main fodder resources during the winter period listed by respondents from five dzongkhags

conservation in Bumthang (Figure 26). Traditionally only one cut was taken from these areas which are dominated by *Schizachyrium delavayi, Eragrostis nigra* and *Potentilla* sp (Roder 1983c).

Figure 25: Herder migrating with animals to lower elevations in the south

The need for fodder preservation in cold temperate areas such as Bumthang has increased with the reduction in cattle migration, the shift to smallholder livestock systems, and the improved milk production potential of crossbred animals (Figure 27). At the same time the options for fodder preservation and the types of winter feed available to farmers have increased due to the fodder extension programmes.

A survey on the management of lactating cows in Bumthang in 1996 found that a wide variety of mostly traditional winter feeds were used (Tables 22 and 23) (RNR-RC Jakar 1997a). Hay and buckwheat straw were the most important feeds. Although not a traditional crop, maize residue was used in February and March. However, the total amount of fodder provided was far below livestock maintenance requirements. The average dry matter provided was 4.9 kg per milking cow per day in February, 1.9 kg in March, 0.5 kg in April, and 1.1 kg in May. This suggests that the cows were grazing permanent grassland to supplement their feed requirements (Table 22). The survey found no relationship between milk yield per animal and hay quantity or total dry matter provided (Figure 28). Improved pasture was grazed throughout the winter and although much less supplementary feed was provided after February, the average milk yield did not decrease significantly. Compared to the hay traditionally made from native grassland species, the quality of hay has improved substantially due to the introduction of white clover *(Trifolium repens)* The farmers ranked grazed clover and grass as the best kinds of feed followed by cut clover and grass, kitchen waste, wild oat *(Avena fatua)* plants (weeds in barley fields), hay, silage, maize residues, and lastly sweet buckwheat straw. These results are shown together with the results of chemical analysis of feed samples in Table 23.

Figure 26: Hay stored for winter feeding

Figure 27: Farmer feeding bull with kitchen waste after a snowfall

Table 22: Fodder resources and quantities used by households with milking cows (1996)

Category	February		March		April		May	
Average daily milk yield (litres/cow)	3.0		2.4		2.5		2.4	
Total dry matter of feed provided (kg/cow/day)	4.9		1.9		0.5		1.1	
Grazing improved pasture (%)	9		32		56		63	
Feed type[1]	%[2]	kg[3]	%	kg	%	kg	%	kg
Hay	91	2.4	71	1.3	15	0.4	-	
Sweet buckwheat straw	70	1.5	21	0.6	-		-	
Concentrate flour	55	0.4	32	0.4	6	0.2	4	0.2
Pumpkin	48	0.5	-		-		-	
Kitchen waste	39	0.6	53	0.5	35	0.5	8	0.3
Sweet buckwheat leaves	27	1.1	9	1.6	-		-	
Turnip	30	0.6	3	0.5	-		-	
Maize residues	21	1.1	6	1.5	-		-	
By-products of alcohol production	18	0.5	21	0.8	3	0.2	4	0.3
Radish	18	0.4	-		3	0.1	-	
Silage	9	2.3	6	0.4	0		-	
Rice husks	6	0.7	0		-		-	
Oats (from wheat/barley fields)	-	-	-		21	0.9	8	2.8
Cut clover and grass	-	-	-		3	1.0	29	2.8

[1] Other types of feed mentioned by one household each were mustard oil and fodder beet in February and willow leaves in March; [2] per cent of households using the particular feed; [3] kg provided per animal per day (averaged among those households using the feed)

Source: RNR-RC Jakar, 1997

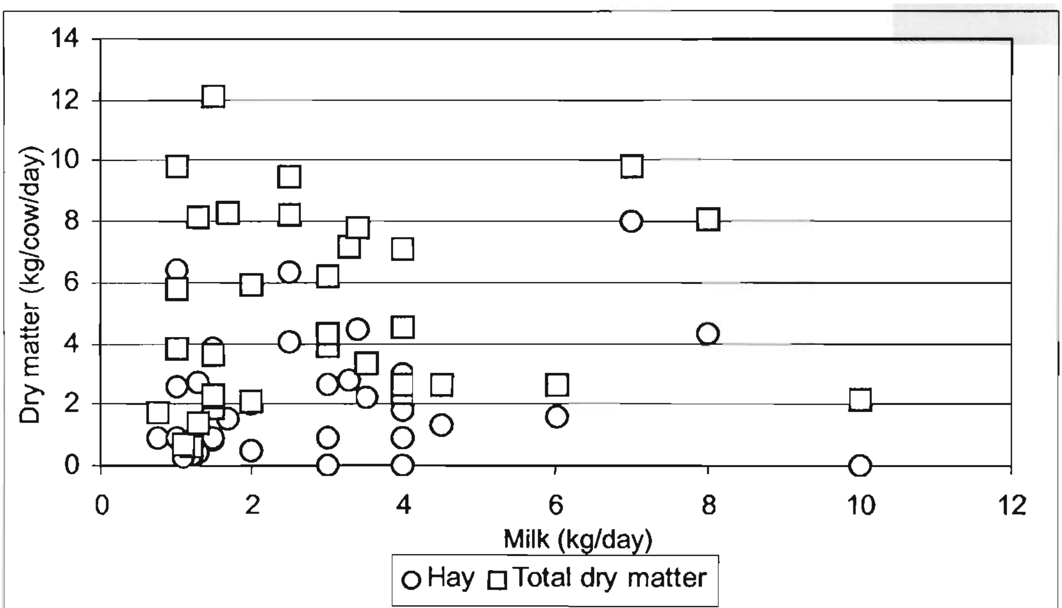

Figure 28: Daily milk yield, hay dry matter and total dry matter provided in February

Table 23: Chemical analysis of selected feed samples

	Rank[1]	No. of samples	CP[2] (%)	CF[2] (%)[3]	EE[2] (%)	NFE[2] (%)
Grazed pasture – March	8	4	30.6±1.92[3]	13.4±2.25	2.53±1.00	41.5±0.74
Grazed pasture – April	8	10	26.9±1.68	13.0±1.27	3.07±0.27	46.7±1.50
Clover/grass cut	7	1	25.8	16.8	2.53	45.0
Kitchen waste	6	9	19.8±2.58	14.3±1.38	3.50±0.63	53.6±4.11
Sweet buckwheat leaves	-	3	17.6±2.44	8.5±1.55	1.51±0.12	60.7±2.81
Oats (wheat/barley fields)	5	4	14.6±2.51	22.2±0.18	2.14±0.29	51.1±3.46
Hay	4	53	17.6±0.48	28.3±0.44	1.46±0.08	41.8±0.74
Silage	3	3	15.3±0.47	35.4±1.20	2.18±0.08	37.7±0.74
Maize residues	2	10	6.1±0.67	29.1±0.84	1.46±0.084	41.8±0.74
Sweet buckwheat straw	1	9	5.7±0.48	42.8±1.51	11.7±10.5	42.8±1.40
Rice husk	-	1	5.22	33.27	0.59	30.0

[1] Rank of fodder quality from the farmer survey described above (RNR-RC Jakar 1997a), a higher number means higher rank; [2] CP – crude protein; CF – crude fibre, EE – ether extract; NFE – nitrogen free extract; [3] standard error

Source: RNR-RC Jakar 1997a

Chapter Three
Research

Introduction

Innovative Bhutanese farmers have always experimented with new production methods and new species and varieties. The introduction of plants such as chilli, maize, and potato in the sixteenth century and the crossbreeding programme with mithun are testimonies to the ingenuity, curiosity, and adaptability of Bhutanese farmers.

The first documented research activities in the livestock and forage sector sponsored by the Government of Bhutan started in the early 1970s (Roder 1990a). Reviews have been carried out of the research systems under the Ministry of Agriculture in general (MOA/ISNAR 1992) and research programmes focused on the development of fodder resources in particular (Roder 1989; Roder and Dorjee 1990; Roder 1990c; Roder 1996a). Initial modest research efforts in the 1970s resulted in the development of widely used technologies. The positive results of the initial activites generated broad support for further research. At the same time the RGOB provided generous subsidies for extension activities. This momentum was not, however, sustained and the research programmes were gradually reduced and in some cases replaced by seed production programmes. The enthusiasm for fodder research waned as a result (Roder 1989; Roder 1990c). With the reorganisation of the research system within the Ministry of Agriculture in the last decade, research in fodder resource development is again receiving attention, although not as much as it warrants, given the need.

Matching the limited resources with the research needs of the variable production systems will always be a challenge in Bhutan. Rigorous priority setting and judicious planning is crucial. In the past, research activities have been largely limited to the following (Roder 1989).

- Cataloguing the resources and their management
- Monitoring trends in the resource base and livestock production
- Identifying and importing useful information and technologies
- Adapting useful technologies

Institutions

Before 1995

Early introductions of exotic fodder species such as kikuyu *(Pennisetum clandestinum)* and Napier grass (*Pennisetum purpureum)* were probably made by enterprising farmers or government officials in the early 1900s. Selected subtropical species were introduced to Samtse in the early 1960s (Wangdi 1979). The first documented introduction of white clover was made in Gogona in 1970 (Maurer 1985).

The main institutions with a fodder research component prior to 1995 are listed in Table 24. The first planned experimental activities focusing on fodder resource development were initiated by the Rural Development Programme (RDP) in Bumthang in 1974. Activities under this project increased steadily through the 1970s and reached a peak in the early 1980s (Figure 29) (Roder 1996a). Fodder development was an important component of the two large livestock development projects (Roder 1989): the Highland Livestock Development Project (HLDP) and the High Altitude Area Development Project (HAADP). Other institutions and projects with research components in the 1970s and 1980s included the Lingmethang

Table 24: Main institutions and projects with a fodder research component prior to 1995

Project/Institution	Period	Major focus
Samtse institutions		
Samtse Livestock Farm	1969-86	• Subtropical forage grown for on-station feeding of livestock
Subtropical Fodder Research Centres (Samtse/Pemagatshel)	1986-95	• Germplasm introduction and testing • Soil fertility
Bumthang institutions		
Rural Development Project	1974-82	• Forage germplasm introduction and testing (temperate and subtropical) • Forage establishment/management • Tree fodder • Seed production
Grassland and associated fodder research centres	1982-86	• Forage germplasm introduction and testing (temperate and subtropical) • Seed production • Tree fodder
National Fodder Seed Production Centre	1986-95	• Seed production
Serbithang institutions		
Grass Seed Multiplication Centre	1976-82	• Seed production
Fodder/Grass Experimental Research Centre	1982-87	• Native fodder plants • Germplasm evaluation
Temperate Fodder Research Centre	1987-95	• Germplasm evaluation
Projects and others		
Highland Livestock Development Project (Eastern Bhutan, Chhukha)	1986-93	• Germplasm evaluation and testing (Subtropical and temperate) • Forage management
Himalayan Pasture and Fodder Research Network (Bumthang)	1986-95	• Germplasm evaluation • Forage management
Applied Research Centre, Yusipang	1988-93	• Forage establishment • Forage management

Source: Adapted from Roder 1989

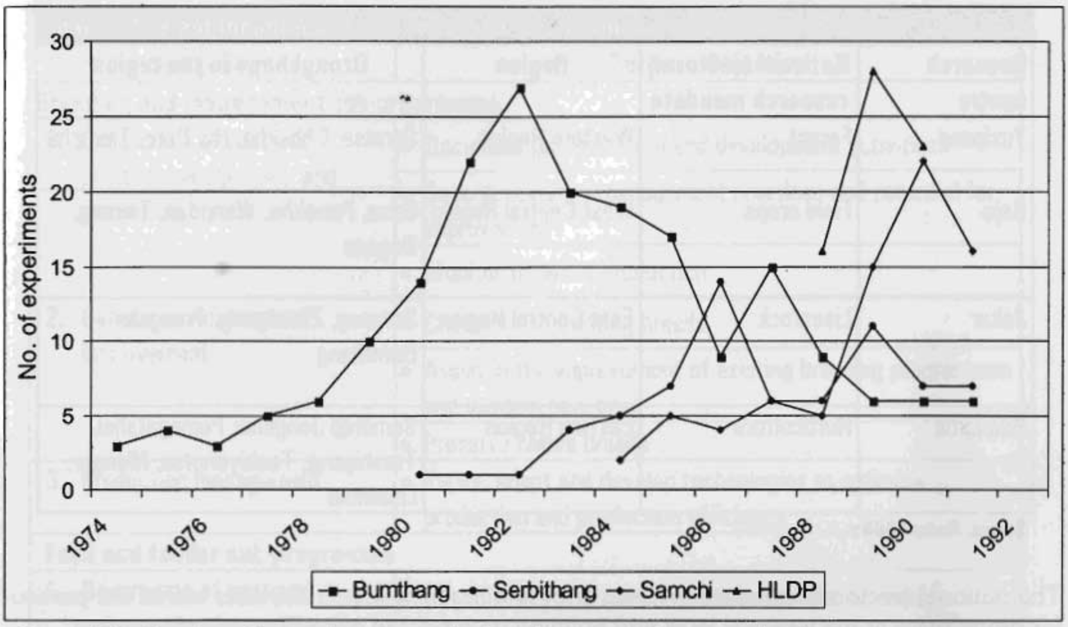

Figure 29: Number of experiments carried out by research centres/projects

livestock farm (1969-80); the Yak and Sheep Project (Bumthang, 1975-80); the Himalayan Pasture and Fodder Research Network (1986-1995); and the Applied Research Centre, Yusipang (1988-93). By 1995/96, the following three major research centres had become established (Roder 1998a).

- the Subtropical Fodder Research Centres at Samtse and Pemagatshel
- the National Fodder Seed Production Centre at Bumthang
- the Temperate Fodder Research Centre at Serbithang

Research activities up to 1995 were either part of development projects or otherwise strongly dependent on outside inputs of expertise and resources. This affected the continuity and focus of research activities. The repeated changes of personnel and focus of the Bumthang and Serbithang centres had a negative effect on the continuity and direction of the research activites (Roder 1989).

Present research system

The Ministry of Agriculture was reorganised between 1993 and 1996. The following major changes affected agricultural research and development activities (Roder 1998a).

- The research activities previously carried out under the separate departments of agriculture, animal husbandry, and forestry were merged under a new 'Research, Extension and Irrigation Division'. This was later renamed the Department of Research and Development Services.
- A new 'Crop and Livestock Services Division' and a 'Forestry Services Division' were created for the supply of inputs and the management of the state forests, respectively.
- Four 'Renewable Natural Resources Research Centres' (RNR-RCs) were established located at Jakar, Bajo, Yusipang, and Khangma. Each of these centres was entrusted with both a regional and a national mandate (Table 25).

Table 25: The renewable natural resources research centres, their mandates and regions			
Research centre	**National (sectoral) research mandate**	**Region**	**Dzongkhags in the region**
Yusipang	Forest	Western Region	Samtse, Chhukha, Ha, Paro, Thimphu
Bajo	Field crops	West Central Region	Gasa, Punakha, Wangdue, Tsirang, Dagana
Jakar	Livestock	East Central Region	Sarpang, Zhemgang, Trongsa, Bumthang
Khangma	Horticulture	Eastern Region	Samdrup Jongkhar Pemagatshel, Trashigang, Tashiyangtse, Mongar, Lhuentse

Source: Roder 1998a

The national (sectoral) mandate involves coordinating all research activities within the particular programme at the national level and building up a pool of expertise and information specific to the particular programme.

In addition to their sectoral mandates, all the RNR-RCs are entrusted with a regional mandate, which gives each centre the responsibility for all research activities under the sectors of field crops, forestry, horticulture, livestock, and farming systems for their respective regions. These responsibilities include:

- building up a pool of expertise and information;
- importing, adapting, and generating technologies to be used in extension programmes;
- supporting extension and development programmes, training, and general backstopping.

Research in the livestock sector

The RNR-RC Jakar is responsible for the coordination of the national livestock research programme. The livestock research programme is made up of separate breeding and management, feed and fodder; and health sub-programmes (Table 26).

It was assumed that 'technologies' under the breeding and management and health sub-programmes would to a large extent be imported from outside Bhutan with little or no need for further adaptation, thus major emphasis has been given to the feed and fodder sub-programme. Around 75% of the total resources for livestock research have been allotted to this programme (RNR-RC Jakar 1997c).

Responsibility for the implementation of the health sub-programme was delegated to the Royal Veterinary Epidemiology Centre, Serbithang, which is part of the Crop and Livestock Services Division (RNR-RC Jakar 1997d).

Since 1996, the RNR-RC Jakar has organised regular annual research review and planning meetings in the livestock sector (RNR-RC Jakar 1996a, 1997d, 1998b, 1999). These meetings have been important for the national coordination of research efforts.

Table 26: Sub-projects under the livestock programme	
Sub-project	**Purpose/Objective**
Breeding and management sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing management practices and potential for improvement
	• Monitor trends in production
2. Genetic evaluation and improvement	• Characterise existing breeds
	• Assist in the improvement of existing breeding programmes and develop new ones
	• Preserve native breeds
3. Production management	• Verify, adapt and develop technologies to optimise production and production efficiency
Feed and fodder sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing fodder resources and their management and potential
	• Monitor trends in resource quality and production
2. Genetic evaluation and improvement	• Characterise native grassland and fodder species
	• Import and evaluate exotic species
3. Production management	• Verify, adapt, and develop technologies to optimise production and to optimise synergic effects between fodder production and other components.
Health sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing management practices (including traditional health practices)
	• Monitor the cost and the impact on animal health of veterinary practices
2. Epidemiological and zoonotic studies	• Study the economic importance and epidemiology of major livestock diseases
	• Identify and describe indigenous parasites and other non-specific diseases
3. Production management Treatment practices	• Verify, adapt, and develop technologies to improve animal health

Source: RNR-RC Jakar 1997c

All four RNR-RCs are strongly committed to feed and fodder research. As described above, the research activities have been divided into three main areas (Table 26).

- the description of past and present management, and monitoring trends;

- genetic evaluation and improvement; and
- production management.

These headings are used for the presentation of past research activities in the following part of this chapter.

Research needs, priorities and constraints

In the early phases little attention was given to identifying research needs and priorities at the producers' level. The pioneering institutions at Samtse Farm and RDP-Bumthang initiated their first research programmes to improve the supply of fodder for their breeding stock. Although these research activities had a strong impact on the extension programmes, due to the lack of rigorous priority setting, some important issues were neglected. The major gaps were in the identification of nutritional limitations; the description of natural vegetation and existing fodder resources; and the production and management of winter feed.

A systematic ranking of research priorities at national level was first carried out in 1989 (Roder 1989) and again in 1996 (RNR-RC Jakar 1996a) (Table 27). In 1989 priorities were further ranked within each area of research (Roder 1989; 1990c). The two top priorities identified at the national level in 1989 were to identify the main nutritional limitations, and to promote fodder production from intensively managed permanent grassland near to settlements. These two priorities remained unchanged in the 1996 ranking.

Research activities carried out between the 1989 and 1996 reviews generated little information towards a better understanding of the main nutritional limitations. Compared to the

Table 27: Ranking of national level research priorities

Areas of research	Priority ranking[1]	
	1989	1996
Identification of the main nutritional limitations to animal production (seasonal fodder production, deficiencies in energy, protein, and minerals)	1	1
Intensively managed permanent grasslands (small plots in the vicinity of settlements, including orchards)	2	2
Arable fodder (in rotation or combination with annual crops, winter fodder) for fodder, soil improvement, and soil conservation	5	3
Tree fodder, agroforestry, and silvopastoral systems	3	4
Extensively managed permanent grassland (rangeland)	4	4
Use of crop residues and by-products (paddy straw, maize stems, buckwheat stems, home brewing)	6	4
Technology development to support various programmes (seed production, fodder conservation etc)	8	5
Grazing effects on forest systems	not included	5
Social and cultural aspects (migration, culling of unproductive animals, land ownership, communal agreements on protection of crops)	7	6

[1] Lowest number indicates highest priority

Source: 1989 -- Roder 1989; 1996 -- RNR-RC Jakar 1996a

1989 ranking, the 1996 ranking saw a shift towards work on fodder resources as a part of integrated systems. Arable fodder and fodder grown in rotation systems moved up from being the fifth priority area in 1989 to the third in 1996. Research on the use of crop residues was also given more importance in the 1996 ranking. These changes were probably due to the change in the research system as the integration of crop, horticulture, livestock, and forestry research has placed more emphasis on fodder production in crop or horticulture systems.

Regional priorities will often differ from the national priorities. At higher elevations extensively managed permanent grassland is the main concern, whilst at lower elevations arable fodder, tree fodder, and crop residues have most importance. Regional research priorities, needs, and opportunities are currently being reviewed by the newly-formed research centres.

The constraints to successful research were assessed at the same time as the research priorities were worked out (Table 28). The lack of rigorous priority setting was considered to be the main constraint in 1989 and 1996. The insufficient academic level of research personnel has remained the second most important constraint.

One of the main problems in research has been the poor progress in building up the capacities of human resources in subjects such as fodder agronomy and range management. Many of these personnel have received training in India and the lack of progress can be at least partly ascribed to Indian animal production science being dominated by veterinary science. While this may be appropriate for India, where livestock production is largely based on using concentrates and crop by-products as feed, it is not suitable for Bhutan where grasslands are the major feed resource.

Table 28: Constraints to successful research in feed and fodder

Constraint/limitation	Rank 1989	Rank 1996
Lack of focus and unrealistic identification of research needs	1[1]	1
Insufficient academic background of research personnel	2	2
Insufficient interaction with farmers and herders and poor representation of target environments	5	2
Insufficient access to information	not included	3
Insufficient research personnel	4	3
Wrong priorities	8	4
Most experimental activities are limited to on-station work	4	5
Lack of coordination with extension activities	7	6
Motivation of Bhutanese research personnel	3	7
Lack of funds	9	7
Lack of equipment	7	8
Too much dependence on expatriate advice	7	9
Insufficient support by the Ministry	8	10
Too much time taken up by administrative work	not included	11

[1] Constraints ranked in declining order of importance (lowest number indicates most serious constraint)
Source: 1989 – Roder 1989; 1996 – RNR-RC Jakar 1996a

Research under 'Past and present management and monitoring trends'

Three main areas are covered under this heading: to document past research and development activities; to describe the existing fodder resource and its management and potential; and to monitor trends in resource quality and production.

Identifying the nutritional limitations to animal production was given the highest priority in both the 1989 and the 1996 ranking exercises. This suggests that there is a perceived lack of quantitative information about fodder resources, farmers' practices, nutritional constraints to livestock production, and the quality of existing fodder. Although there are numerous references on these topics, from the detailed description of Bhutan's vegetation given by Griffith (Griffith 1839) to the extensive nationwide investigations on fodder resource use by the RNR-RC Jakar in 1997 (Table 29) (RNR RC Jakar 1997a; Roder 1998b), there is still much to be done. The great variations in climate, soils, and topography has resulted in a wide range of vegetation, fodder sources, and production systems and thus the description of these fodder resources and the management practices has been a tremendous challenge for the few researchers involved . The existing descriptions of fodder resources and their management have been covered in Chapter 2.

It is expected that in future the monitoring of trends in the quality of the resource base will become more important. Considering the fragility of the grassland resources and the potentially harmful effects that management interactions may have on biodiversity, and on forest, water and agricultural resources, it will be important to build up mechanisms and develop key indicators which can quantify trends and changes over time (RNR-RC Jakar 1997c). This part of the research programme is still in its infancy, however.

Research under 'Genetic evaluation and improvement'

The characterisation of native species and the introduction and evaluation of exotic species have been the main activities under the genetic (germplasm) evaluation and improvement programmes. To date most of the fodder resources, except for crop residues, originate from native plant species. Yet limited information is available on the production potential and nutritional qualities of most of these species. In the 1970s it was expected that the fastest gains in fodder development would be made by introducing exotic fodder species, therefore much emphasis was placed on the introduction and testing of new species and varieties.

Evaluation and description of native species

Little has been accomplished in the description and evaluation of native species. The plant communities of major grassland ecosystems remain poorly documented and there are hardly any descriptions of individual species. Indications of nutritional qualities are only available for the grassland species *Schizachyrium delavayi* and *Lespedeza* sp (Roder 1983c; Roder et al. 1997b) and for less than 20 woody perennials (Roder 1981b, 1982d; Tamang 1987). The yield of some tree fodder species has been estimated on the basis of farmers' assessments (Tshering et al. 1997a) and by extrapolating from a few single tree measurements (Roder 1992).

Of all the native species, willow has received the most attention. Observations have been made of its nutritional quality over the growing season (Roder 1992, Wangdi et al. 1997, 1998), its dry matter accumulation over the growing season (RNR-RC Jakar 1997a; Wangdi et al. 1997), its potential for hay or silage making (Premasiri 1988; Roder 1992), and its intake by sheep (Premasiri 1988) and cattle (Roder 1992).

Table 29: References relating to fodder resources and their management in Bhutan	
Activity	References
Geophysical	
Geology	Eguchi 1987a; Ganser 1983; Karan 1967
Climate	Eguchi 1987b; Karan 1967; Negi 1983; Roset 1998
Soil	Campbell 1983; Gibson 1989c; Murtagh 1983; Okazaki 1987; Roder 1982a; Sargent et al. 1985
Vegetation	
Vegetation general/Flora	Grierson and Long 1983, 1984, 1987, 1991; Griffith 1839; Noltie 1994, 2000; Oshawa 1987b; Stearn 1976
Grassland vegetation	Dunbar 1979; Dunbar 1981; Gyamtsho 1996; Harris 1987; Miller 1987a, 1987b; Miller 1989a; Noltie 1994, 2000; Numata 1987a; Roder 1983c; Roder 1990a; Tsuchida 1987, 1991
Fodder resources and their management	
Early descriptions of fodder resources	Fischer 1971; Griffith 1839; Murtagh 1983
Institutions influencing resource use	Roder et al. 1987; Roder 1989
Grassland resources	Dorjee 1986; Gyamtsho 1996; Harris 1987; Miller 1987d, 1987e; Miller 1989a; Noltie 1994, 2000; Roder 1983c; Rumball 1988a; Singh 1978
Pastoralism	Dorjee 1993; Gibson 1991; Gyamtsho 1996; Harris 1987; Miller 1987b, 1987c, 1987g; Ura 1993; Wangmo 1984
Wildlife/livestock interactions	Gyamtsho 1996; Miller 1988a; Wangdi 1979
Tree fodder	AHD undated; Bajracharya 1990; Gyeltshen 1984; Premasiri 1988; Roder 1981a, 1982d, 1985, 1992; Tamang 1987; Tshering et al. 1997; Wangdi et al. 1997, 1998
Crop residues	AHD 1987; RNR-RC Jakar 1997a; Roder 1998c; Verma 1984; van Wageningen 1985, 1986
Winter feed	RNR-RC Jakar 1997a; Roder 1983c, 1998b, 1998c
Fodder quality (including antinutritional)	Bajracharya 1990; Denzler et al. 1993; Gyamtsho 1996; Premasiri 1988; RNR-RC Jakar 1997d; Roder 1981a, 1982d, 1993; Tamang 1987; Winter et al. 1992, 1994a, 1994b

Introduction and initial screening of exotic species

The methodical introduction of germplasm and its evaluation started in the early 1970s. Since then a large number of species and cultivars have been evaluated for their fodder production potential across a wide range of environments (Figure 30, Annex 2). About 50% of all the species evaluated so far were introduced to Bhutan before 1983. Except for ruzi grass *(Brachiaria ruziziensis)*, all species that are presently recommended for extension were selected before 1982. For obvious reasons it was much easier to identify species and cultivars in the early phases of these activities when no exotic fodder species were present in the country.

Figure 30: Introduction nursery temperate species (Bumthang 2,700m)

Once most of the important fodder species had been evaluated, the chances of identifying a superior species or cultivar decreased.

Germplasm introduction and testing generally included initial screening in on-station, single-plot observation nurseries, followed by multilocational testing (on-station and on-farm) with farmers' participation. The most successful species were then released for inclusion in extension programmes. The species tested so far, and stage of testing, are listed in Annex 2.

The RDP Bumthang played a key role in the introduction and testing of germplasm. Other institutions and projects with documented germplasm introduction and screening activities included Samtse livestock farm and the Samtse Subtropical Fodder Research Centre; the Serbithang Grass Seed Multiplication Centre and Temperate Fodder Research Centre; the Highland Livestock Development Project; the Himalayan Pasture and Fodder Research Network; and the RNR-RC Jakar (Roder 1989, 1996a).

The germplasm introduction and evaluation programmes have always paid major attention to the selection of legume species that may be suitable for grassland improvement, fodder production in crop and horticulture systems, green manure, and soil conservation (RNR-RC Jakar 1996a). It was recognised early on that native grasslands lack suitable legumes whilst the available grass species had good potential for fodder production. It was expected that crop yields, soil conservation, and labour productivity could be improved by incorporating fodder production with legumes in the traditional crop and horticulture systems.

Yield studies for selected species and cultivars

Substantial information is available on the production and growth of temperate fodder species from tests performed at several different locations over several years (Table 30). With only a few exceptions, white clover, red clover *(Trifolium pratense)*, lucerne *(Medicago sativa)*, and lotus *(Lotus pedunculatus)* were the highest yielding legumes. The highest yielding grass species have been cocksfoot *(Dactylis glomerata)*, tall fescue *(Festuca arundinacea)*, and Italian ryegrass *(Lolium multiflorum)*.

Only limited observations have been made of the yields of subtropical species. Most species and cultivars that have been assessed as suitable have been selected on the basis of visual assessments of their yield potential and their persistence.

Compatibility in mixtures

Most perennial fodder species are grown in mixtures combining grass and legume species. Species in a mixture have to be compatible and need to have similar management and

Table 30: Yield of selected temperate perennial fodder species				
Location		**Batbalathang (Bumthang)**	**Karsumphe (Bumthang)**	**Serbithang (Thimphu)**
Elevation		**2,650m**	**2,700m**	**2,600m**
Period/duration		1980-82 (3 years)	1983-85 (3 years)	1990-93 (4 years)
Reference		Roder 1983c	Gyamtsho 1985	AHD 1990
Legume yield relative to white clover (%)				
White clover	*Trifolium repens*	100 (6)[1]	100 (1)	-
Crown vetch	*Coronilla varia*	-	27 (1)	-
	Latyrus silvestris	-	43 (1)	-
Birdsfoot trefoil	*Lotus corniculatus*	92 (2)	24 (2)	-
	Lotus pedunculatus	111 (1)	17 (1)	-
	Medicago glutinosa	94 (1)	-	-
	Medicago media	-	66 (9)	-
Lucerne	*Medicago sativa*	72 (15)	87 (3)	-
Alsike clover	*Trifolium hybridum*	76 (1)		-
Red clover	*Trifolium pratense*	103 (11)	84 (2)	-
	Trifolium semipilosum	89 (1)		-
	Vicia tenuifolia	-	53 (1)	-
Grass yield relative to cocksfoot (%)				
Cocksfoot	*Dactylis glomerata*	100 (8)	100 (3)	100 (7)
Tall oat grass	*Arrhenatherum elatius*	79 (6)	-	-
Tall fescue	*Festuca arundinacea*	105 (3)	96 (1)	148 (7)
Meadow fescue	*Festuca pratensis*	93 (4)	-	-
Red fescue	*Festuca rubra*	87 (2)	99 (2)	141 (3)
Italian ryegrass	*Lolium multiflorum*	112 (4)	93 (2)	96 (5)
Perennial ryegrass	*Lolium perenne*	78 (4)	-	194 (3)
	L. multiflorum x perenne	59 (3)	-	138 (2)
Bahia grass	*Paspalum notatum*	-	76 (1)	-
Common meadow grass	*Poa pratensis*	73 (1)	98 (2)	85 (1)
Timothy	*Phleum pratense*	86 (4)	-	42 (1)

[1] Value ( ) indicates numbers of cultivars under observation and used to calculate average yield.

environment requirements. Thus when evaluating germplasm it is necessary to test combinations of potential partners.

Considerable work has been done on comparing grass mixtures for temperate areas, but as yet there are no quantitative data on subtropical species used in mixtures.

Information on the performance of temperate species in mixtures was collected under a range of conditions and included on-station and on-farm studies with mixture treatments, and observations made on production plots sown on a government farm. Mixtures were generally sown following recommended practices (see Chapter 4 on extension). The persistence and contribution of the seeded species was observed over periods of from 1-20 years. The relative contribution of a particular species was measured on the basis of its contribution to the total biomass (weight) or its presence in quadrats (frequency).

Experiences with mixtures have been reviewed by Roder et al. (1997a). Meadow fescue (*Festuca pratensis*), perennial ryegrass (*Lolium perenne*), common meadow grass (*Poa pratensis*), red fescue (*Festuca rubra*), and timothy (*Phleum pratense*) were used as the main grass species for establishing permanent pastures in the initial fodder development programme in Bumthang (Roder 1983d; Roder et al. 1997a). This was based on recommendations from experiences in northern Europe and Switzerland (Klapp 1971).

Between 1975 and 1980, about 50 ha of grassland at altitudes between 2580 and 2900m were sown with mixtures containing over 70% of the above species (meadow fescue, perennial ryegrass, common meadow grass, red fescue, and timothy) (Table 31). However, most of these grass species disappeared within a few years of sowing. Grazing and cutting management either delayed or enhanced this process in some plots but the end result remained the same. By 1997, meadow fescue, perennial ryegrass, and timothy had disappeared completely and only minor traces of common meadow grass were left. Red fescue was dominant in one plot while cocksfoot and tall fescue, although they had been used at lower rates, had increased to higher frequencies and come to contribute substantially to the total biomass of the grassland.

Table 31: Mixtures used in on-farm trials between 1975-1980

Species	Scientific name	Seed rate (%)	Frequency 1997[1]
White clover	*Trifolium repens*	16	80
Cocksfoot	*Dactylis glomerata*	12	52
Red fescue[2]	*Festuca rubra*	4.5	13
Tall fescue	*Festuca arundinacea*	12	10
Italian ryegrass	*Lolium perenne*	4	3
Common meadow grass	*Poa pratensis*	1.5	0.5
Birdsfoot trefoil	*Lotus corniculatus*	0.3	0
Meadow fescue	*Festuca pratensis*	25	0
Perennial ryegrass	*Lolium perenne*	19	0
Timothy	*Phleum pratense*	6	0
Local grasses		-	10
Total		100%	

[1] Frequency of occurrence in 0.0625 m^2 quadrats; [2] red fescue was mostly limited to one extensively managed plot
Source: Roder 1983d; Roder et al. 1997a

The results from the large area sown at the RDP-farm were confirmed by an on-station study initiated in 1980. In this study the performance of 10 mixtures containing different species and variety combinations was observed under grazing and cutting management and with three levels of P fertiliser application (Figure 31, Table 32). The seed rates used for the different species were based on seed weight and the expected contribution of the individual species. Germination was satisfactory for all the species and varieties included. The relative contribution of the individual species to the dry matter production was measured in the year of establishment and from the first harvest in the two succeeding years. The most important findings from these studies were that:

- screening species and cultivars only in pure stands and/or under cutting treatments (without grazing) is not sufficient to assess their potential in permanent grasslands and as long-term leys;

- in seed mixtures with white clover, the contribution of the legume to the dry matter production was about 70%, while in seed mixtures with red clover, the legume contribution was about 85%;
- the dominance of white clover could be manipulated by choosing different white clover cultivars. The average white clover contribution to the dry matter production was 78% for mixtures containing Ladino, 75% for mixtures with Ladino and Milkanova cultivars mixed together, and 60% for mixtures with Milkanova only;
- birdsfoot trefoil *(Lotus corniculatus)* did not make a significant contribution to dry matter production when used in a mixture with white clover;

Figure 31: Evaluating mixtures under grazing conditions

Table 32: Average contribution to total biomass by species used in the RNR-RC Jakar mixture trial

Species/cultivar		Seed rate (kg/ha)	No of mixtures	Botanical composition[1] (%)				
				Cutting only			Grazed	
				1980	1981	1982	1981	1982
Red clover	*Trifolium pratense*	5	1	93	87	76	not included	
White clover – Ladino	*Trifolium repens*	4	2	89	80	72	72	75
White clover – Milkanova		4	1	70	72	38	48	68
White clover – Milkanova & Ladino		4	4	81	82	68	65	77
Cocksfoot – Reda	*Dactylis glomerata*	5-15	2	15	22	36	22	10
Cocksfoot – Baraula		5-15	4	16	19	32	26	10
Tall oat grass	*Arrhenatherum elatius*	9	1	1	2	4	not included	
Yellow oat grass	*Trisetum flavescens*	1-3	2	<1	<1	0	<1	3.5
Red fescue	*Festuca rubra*	3	1	<1	0	0	5	<1
Perennial rye – Vigor	*Lolium perenne*	6-7	2	5	2	0	<1	<1
Perennial rye – Barvestra		7	2	1	<1	0	<1	0
Short rotation ryegrass	*Lolium multiflorum x L. perenne*	8-15	2	6	<1	0	0	1
Common meadow grass	*Poa pratensis*	4-6	2	<1	<1	0	<1	0
Meadow fescue - Merbeem	*Festuca pratensis*	10-12	6	1	<1	0	<1	0
Timothy - Topas	*Phleum pratense*	2-4	6	0	0	0	<1	0

[1] Relative contribution of the individual species to dry matter production measured in the year of establishment and from the first harvest in the two succeeding years

Source: Roder 1983c; Roder et al. 1997a

- of all the grasses tested, only cocksfoot could secure a significant percentage, but there was no difference between the two cocksfoot cultivars used. Tall fescue and Italian rye were not included in the study;
- other grass species that showed some promise were yellow oat grass *(Trisetum flavescens)* and red fescue.

Having a high proportion of white clover in grazing areas is often seen as disadvantageous as it causes bloat in livestock, needs frequent cutting or grazing, and has a high P-requirement and limited drought tolerance (Roder et al. 1997a). Therefore, in 1990 a second series of trials was initiated to:

- identify grass species that can compete with white clover;
- develop mixtures suitable for temperate areas of Bhutan; and
- compare recommended mixtures with other mixtures.

There were three trials in the series, all involving on-farm assessment of seed mixtures.

The 'on-farm mixture trial 1 (1990)' was a nationwide trial initiated in 1990 using five different mixtures of forage seed (NFSPC 1994). The mixtures used included the species recommended for extension (white clover, cocksfoot, tall fescue, and Italian ryegrass) as well as variations which included common meadow grass, meadow foxtail *(Alopecurus pratensis)*, prairie grass *(Bromus catharticus)*, and lotus. The mixtures were evaluated in farmers' fields in the Paro, Thimphu, Wangdue, Trongsa, and Bumthang dzongkhags. All species germinated well and had on average eight or more plants per square metre one year after establishment (Roder et al. 1997a). The contribution of common meadow grass, meadow foxtail, and tall fescue to the total biomass was small. One year after establishment there was less than one plant each of common meadow grass, meadow foxtail, and prairie grass in each square metre in three of the six sites (Ritchie 1992).

The 'on-farm mixture trial 2 (1994)' involved testing of a mixture containing the recommended species (white clover, cocksfoot, tall fescue, and Italian ryegrass) with the addition of common meadow grass in the Bumthang dzongkhag. The results are shown in Table 33. The average white clover contribution to the dry matter production was below 50% from the time of the first cutting for all three years tested (Table 33), indicating that white clover dominance is not as serious a problem as often alleged. The percentage of cocksfoot increased slightly over the three-year period, while the white clover percentage decreased. The average contribution of Italian ryegrass decreased from 26% in 1994 to 11% in 1996. The contribution of tall fescue and common meadow grass was insignificant.

Table 33: Species composition of a mixture study carried out on farmers' fields in Bumthang, 1994-96

Species		Botanical composition from first cutting (%)		
		1994	1995	1996
White clover	*Trifolium repens*	44.9±6.0	43.1±11.0	30.5±4.9
Cocksfoot	*Dactylis glomerata*	22.9±8.2	39.7±17.2	35.6±9.0
Tall fescue	*Festuca arundinacea*	0.6±0.4	0.8±0.8	0
Italian ryegrass	*Lolium multiflorum*	25.9±14.1	13.3±8.2	11.4±10.9
Common meadow grass	*Poa pratensis*	0.1±0.1	0.6±0.2	0.1±0.1

Source: RNR-RC Jakar 1996b

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The 'on-farm mixture trial 3 (1996)' involved testing seven mixtures made up of varying amounts of white clover, lotus, tall fescue, Italian ryegrass, cocksfoot, perennial ryegrass, red fescue, common meadow grass, and meadow foxtail in single plot studies on farmers' fields and in one replicated study under on-station conditions. All the species included in the mixtures were found present 50-70 days after seeding (Table 34). As in the 'on-farm mixture trial 1' meadow foxtail and common meadow grass showed a very low frequency, particularly on-station. Perennial ryegrass had the highest frequency in both on-station and on-farm sites, but most plants disappeared during the first winter season.

Table 34: Average establishment of different species averaged over seven different mixtures and four replicates (on-station) or two sites (on-farm)

Species		Seed rate (kg/ha)	No. of mixtures	Frequency[1]	
				On-station	On-farm
White clover	*Trifolium repens*	2-3.75	6	74	61
Lotus	*Lotus pedunculatus*	5	1	85	35
Italian ryegrass	*Lolium multiflorum*	5-7.5	3	81	67
Cocksfoot	*Dactylis glomerata*	5-17.5	7	79	64
Tall fescue	*Festuca arundinacea*	10-15	7	58	61
Perennial ryegrass	*Lolium perenne*	5	4	93	74
Meadow foxtail	*Alopecurus pratensis*	2-10	2	2	20
Red fescue	*Festuca rubra*	5-7	2	74	40
Common meadow grass	*Poa pratensis*	4	1	3	20

[1] Presence in $0.0625m^2$ quadrats (10 per plot) observed 50-70 days after seeding
Source: Roder et al. 1997a

Reviewing these temperate mixture trials, Roder et al. (1997a) concluded that white clover, cocksfoot, tall fescue, and, under specific conditions, Italian ryegrass, are well suited for most temperate areas of Bhutan. These findings confirmed that the choice made in the early eighties to use these species in the extension programme was appropriate. The poor results obtained with perennial ryegrass, meadow fescue, and common meadow grass suggest that these species are not suitable for Bhutan.

The same authors concluded that it is more important to conduct variety trials with the selected species, especially cocksfoot and tall fescue, than to test additional species or conduct further studies of species already deemed unsuitable in the 1970s trials. An effective evaluation of a particular grass cultivar would consider the interaction with the expected companion legume, the type of grazing animals, and current management practices by farmers. Also, further trials with prairie grass, Lincoln grass, and lotus are needed to prove whether or not they offer an advantage over the existing recommended species.

Overall the results of the above trials have not so far resulted in any changes in the species previously recommended for extension from trials prior to 1982 (Roder et al. 1997a). However, many investigations were not followed up for a long enough period to provide conclusive data, whilst others were only poorly documented.

Species recommended for extension

Since the early 1970s, a number of annual and perennial species and varieties have been recommended by various professionals for fodder production in specific environments (Table 35). Some of them have been included in the extension programmes, whilst others are still

Table 35: Species recommended for fodder production in Bhutan

Species	Year[1]	Ref.[2]	Area (ha)[3]	Present status
Annual species				
Oat *(Avena sativa)*	<1975		<100	• Recommended for winter feed
Fodder beet *(Beta vulgaris)*	1982	2	<10	• On-farm evaluation
Hairy vetch *(Vicia villosa)*	1978	1	<5	
Swede *(Brassica napus)*	1982	3	-	• On-farm evaluation
Kale *(Brassica oleracea)*	1982	3	-	
Field pea *(Pisum sativum)*	1978	1	-	
Herbaceous perennials				
White clover *(Trifolium repens)*	1978	1	100,000	• Extension programme since 1978
Cocksfoot *(Dactylis glomerata)*	1978	1	20,000	
Italian ryegrass *(Lolium multiflorum)*	1978	1	15,000	
Tall fescue *(Festuca arundinacea)*	1982	3	15,000	
Kikuyu grass *(Pennisteum clandestinum)*	1982	3	2,000	• Not multiplied, weed problems
Napier grass *(Pennisetum purpureum)*	1982	3	500	• Extension programme since 1980
Greenleaf desmodium *(Desmodium intortum)*			<500	• Provisionally in extension programme for limited periods
Lotus *(Lotus pedunculatus)*	1979	4	<50	
Lucerne *(Medicago sativa)*	1978	1	<5	• Problems in seed production
Red clover *(Trifolium pratense)*	1978	1	-	• Seed production studies
Stylo *(Stylosanthes. guianensis)*	1982	3	<50	• On-farm evaluation
Red fescue *(Festuca rubra)*	1982	3	<10	
Silverleaf desmodium *(Desmodium uncinatum)*	1982	3	-	
Guinea grass *(Panicum maximum)*	1982	3	-	
Setaria (*Setaria sphacelata)*	1982	3	-	
Crown vetch *(Coronilla varia)*	1982	3	-	• Under observation
Glenn joint vetch *(Aeschynomena americana)*	1988	5		
African clover *(Trifolium ruepellianum)*	1988	5		
Woody perennials[4]				
Willow (*Salix babylonica*)	1981	6	100	• Extension programme since 1982
Leucaena leucocephala	1981	7	<5	
Ficus roxburghii	1982	6	5000	
Ficus nemoralis	1982	6	<100	
Bauhinia purpurea	1982	6	<100	
Bauhinia variegata	1982	6	<100	
Artocarpus lakoocha	1982	6	<100	
Litsea polyantha	1982	6	<100	
Brassaiopsis hainla	1982	6	<100	
Saurauia nepaulensis	1982	6	<100	
Prunus cerasoides	1982	6	<100	

[1] Document in which species was recommended for the first time; [2] references: 1 = AHD undated d; 2 = Hickman 1981; 3 = Roder 1982c; 4 = Dunbar 1979; 5 = Gibson 1988b; 6 = Roder 1982b; 7 = Tenzing 1981b; [3] area cultivated in 1996 estimated by authors based on achievements reported and survey results; [4] area for woody perennials based on 200 trees per ha

under investigation or have been discarded due to seed production problems, limited potential, or other reasons. Species recommended and later discarded include Kenya white clover *(Trifolium semipilosum)* - due to low production (Roder 1983c); Jerusalem artichokes *(Helianthus tuberosus)* - due to wild boar problems; and meadow fescue and perennial ryegrass - due to poor persistence (Roder et al. 1997a).

Some of the most important species recommended are described below.

White clover – White clover has been the most widely used exotic fodder species in Bhutan and has proven to be the most suitable legume for grassland improvement over a wide range of conditions between 2,000m and 4,000m altitude (Gyamtsho 1996). Its first recorded introductions were made in 1970 and 1974 (Roder et al 1997b). In extensive testing over a range of locations at elevations of between 1,500 and 4,000m, red clover, lucerne, birdsfoot trefoil, and other lotus varieties produced dry matter yields equal to that of white clover; however, they were less persistent and gave lower yields under grazing (Roder 1983c).

Initial white clover establishments were only successful when seeds were inoculated with the appropriate rhizobia and sufficient P fertiliser was provided. With higher P application rates, dry matter yields reached up to 11t ha^{-1}. The potential for dry matter yield increases through white clover introduction and P application, but the effect of P decreases with increasing elevation and decreasing precipitation. Two studies at 4,000m found no significant increase in dry matter production with P fertilisation (Gyamtsho 1996; Roder 1983c).

White clover has excellent nutritional qualities (Table 36). However, its tendency to cause bloat in livestock has sometimes been a serious problem. A survey on attitudes to white clover and numbers of animal lost due to bloat was carried out across five dzongkhags (Roder 1998b); the results are summarised in Table 37. The number of animals lost due to bloat was relatively high in Bumthang and Wangdue, both regions with large areas of white clover based grasslands. Many respondents from these two dzongkhags considered white clover to be a weed (Table 37, Figure 32). However, the majority of respondents from these areas felt that there was no need to replace white clover with other legumes.

Table 36: Fodder quality of white clover compared to local species

Fodder	Crude protein (%)	Crude fibre (%)	P (%)	Starch units
White clover (at flowering)	18	22	0.29	60
Schizachyrium delavayi (before flowering)	5.4	42	0.11	24
Lespedeza sp. (before flowering)	14	35	0.16	-
Local hay	5.0	40	0.17	17
Hay from grass/clover mixture	11.0	30	0.21	50

Source: Roder 1983c

Thanks to the very successful introduction of this species through the extension programme, complimented by its spread through seed carried by grazing animals, white clover is now found throughout Bhutan, especially along roads and waterways and in cropland and grazing land.

Table 37: Farmers' assessment of white clover[1]					
Gewog[2]	No need to reduce clover	Clover causes bloat	Clover is a weed	Animals lost due to bloat	
				(% HH)	(no./HH over 6 years)
Dopjari (P)	83	5	5	0	0
Narja (P)	34	9	79	0	0
Sephu (W)	50	17	45	4	0.05
Phubjikha (W)	95	47	76	36	0.55
Tangsibi (T)	61	33	2	25	0.36
Drakten (T)	92	11	0	2	0.02
Tang (B)	86	68	75	44	1.15
Chumey (B)	25	44	74	22	0.48

[1] For sample size in dzongkhags see Table 5; [2] dzongkhag, P = Paro; W = Wangdue; T = Trongsa; B = Bumthang
Source: Roder 1998b

This fast spread of a newly introduced species is very similar to the expansion of invasive weeds and so has caused some alarm. Some farmers are mainly worried by its bloat inducing properties, whilst others have called for caution in future extension programmes, have denounced it as a serious weed, or even condemned it as a menace to the existing biodiversity (Roder 1996b; Roder et al. 1997b). Although these may be overreactions, there is a need to reassess the place of white clover in future fodder development activities and to identify alternative techniques and species that:

- have lower P requirements and are more efficient in taking up P;
- can accumulate good quality fodder over the entire growing season, which will then be available for winter feed; and
- are less susceptible to water stress.

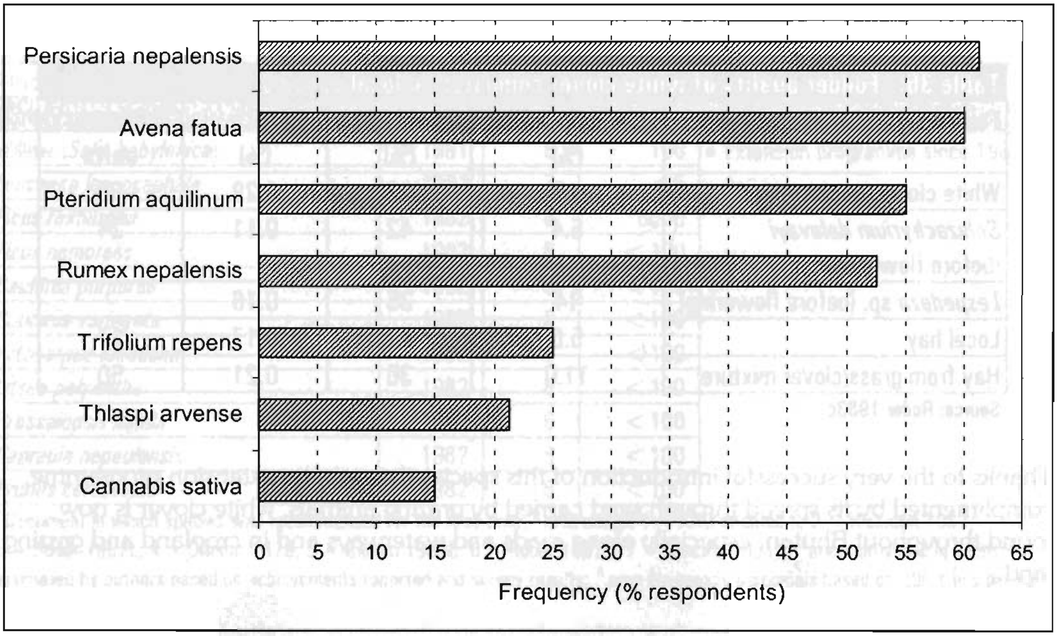

Figure 32: Most important weeds in buckwheat/wheat systems of Bumthang

Cocksfoot – Cocksfoot has a wide distribution throughout Europe, North Africa, temperate Asia, and some Himalayan regions (Bor 1960). Some authors have suggested that the species found in the eastern Himalayas may be a distinct sub-species, different from the European species (Bor 1960).

The first documented introduction of cocksfoot into Bhutan was made in 1974 (Roder 1983d). It appears, however, that the species was already in Bhutan before this date. Cocksfoot was found in permanent grassland systems in Merak Sakten (Eastern Bhutan) in 1976 (Dunbar, personal communications). Compared to exotic varieties, however, the line obtained from Merak Sakten had poor production (Roder 1983c).

Cocksfoot forms tufts and tends to have a high fibre content in advanced maturity (Klapp 1971). For European grasslands it is therefore often considered to be an inferior species (Klapp 1971). It is, however, well adapted to cyclic dry and wet conditions such as those prevailing in Bhutan and it is expected that it will gradually spread through much of the temperate grasslands of the country.

So far about 30 cultivars of cocksfoot have been introduced into Bhutan. However, with a few exceptions, they have not been systematically tested for yield, quality, or persistence (Roder 1983c; Roder et al. 1997a). A European variety 'Amba' is used at present by the extension services. In a review of temperate grass mixtures and species, Roder et al. (1997a) recommended that a systematic evaluation of cocksfoot cultivars should be performed to identify the varieties with the best potential.

Pearl lupine – Pearl lupine *(Lupinus mutabilis)*, a plant from the Andean region of South America, was first introduced into Bhutan in 1977. It was initially introduced as an oil crop, but was found unsuitable because of its high alkaloid content and the difficulties in extracting the oil (Roder 1983e; Roder et al. 1993b). Studies carried out at high elevations in Bumthang and Phubjikha found that pearl lupine was an excellent green manure crop with the following useful properties (Table 38):

- vigorous growth which suppresses weeds;
- high levels of biomass production with rates of 15.6g m^{-2} day^{-1} during peak growth, resulting in high levels of N-accumulation;
- ability to nodulate vigorously with native rhizobia strains; and
- suitability to cool climates and poor soil conditions with low P-availability.

In rotation studies, the yield of potatoes increased by 33 to 34% when the previous crop had been pearl lupine rather than fallow or potato (Roder et al. 1993b). In spite of the excellent results, it was concluded that pearl lupine should not be recommended for extension because farmers require fodder rather than green manure, and pearl lupine is not very palatable.

Table 38: Biomass yield and N and P accumulation by pearl lupine (*Lupinus mutabilis*)

Plant part	Accumulation over 7 months growing season (g m^{-2})		
	Biomass	N	P
Nodules	25	1.2	0.08
Roots	107	1.1	0.12
Stems	1,172	12.9	2.11
Leaves	157	7.6	0.68
Flowers	9	0.4	0.04
Pods	105	4.6	0.58
Total	**1,575**	**27.7**	**3.60**

Source: Roder et al. 1993b

Willow (*Salix babylonica*) – It is not known when this species of willow was first introduced into Bhutan. Early travellers to Bhutan make reference to the abundance of willow trees in Paro and Thimphu valley (Marakham 1876). Today willow is found widely throughout the country at elevations between 800 and 3,000m; it is by far the most important tree fodder species at elevations above 2,500m (Roder 1981b; Roder 1992). Experience with willow as a fodder source have been reviewed by Wangdi et al. (1998).

An initial survey carried out in 1981 in Bumthang dzongkhag (elevation 2,600 to 3,000m) found that willow was clearly the preferred fodder tree species (Roder 1981b). The farmers surveyed were found to have an average of 17.5 willow trees each. Similarly, in eastern Bhutan, farmers indicated their preference for this species (Wangdi et al. 1997). At present no other kind of tree fodder species is planted by farmers in temperate areas of Bhutan.

Willow is a multipurpose tree: farmers value it as a source of fodder but give almost equal importance to its value for fuel and fencing (Figure 33, Table 39). Although farmers appreciate its high fodder quality, they would prefer to have a species that can provide fodder during the dry winter season (Roder 1992; Wangdi et al. 1997). The fluctuations in quality and availability of willow fodder are quite similar to the seasonal pattern of natural grasslands, and the tree leaves drop in November.

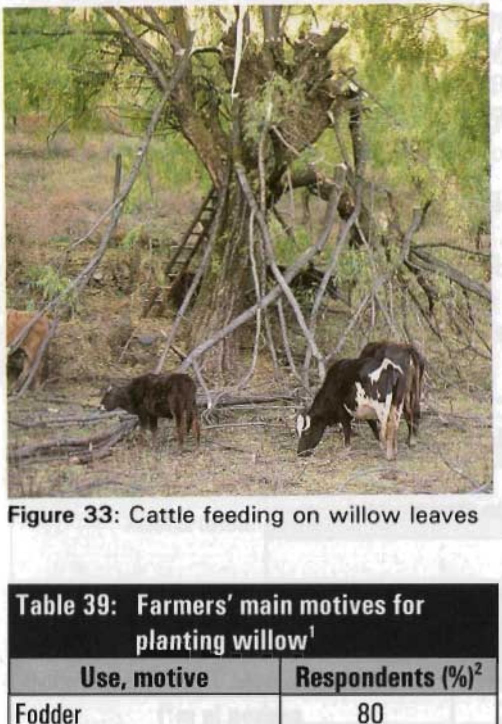

Figure 33: Cattle feeding on willow leaves

Table 39: Farmers' main motives for planting willow[1]

Use, motive	Respondents (%)[2]
Fodder	80
Fencing	77
Fuel	77
Erosion Control	3
For sale (branches for planting)	6

[1] Data from willow survey 1996, the survey covered 35 farmers; [2] the sum is greater than 100% because all farmers gave two or more uses

The fodder quality of willow is discussed elsewhere in this chapter. The yield from existing stands is estimated to be 3.8 to 7.0t of dry matter per ha (Gyamtsho 1986; Roder 1992). The dry matter yield of 5 to 10 year old willow trees increases as the growing season progresses, but starts to decline in October (Figure 34). It is recommended that willow is best cut for feeding to livestock during September and early October before the leaves are shed. By using willow foliage as fodder in October, farmers can save the white clover and grass resources for grazing later in the dry winter period. Combined management of willow and white clover to extend the availability of winter fodder, was recently adopted by the Ministry of Agriculture as an extension recommendation (Roder 1999).

Jerusalem artichokes – This annual species was first introduced to Bhutan by a farmer in the 1970s (Gyamtsho 1986; Roder 1983c). In a number of studies carried out in Bumthang between 1978 and 1983, Jerusalem artichokes produced the highest dry matter yield of all the arable fodder species tested (Roder 1983c). Both tubers and stems can be used as cattle feed. It was therefore recommended as the most promising winter fodder by the RDP and the

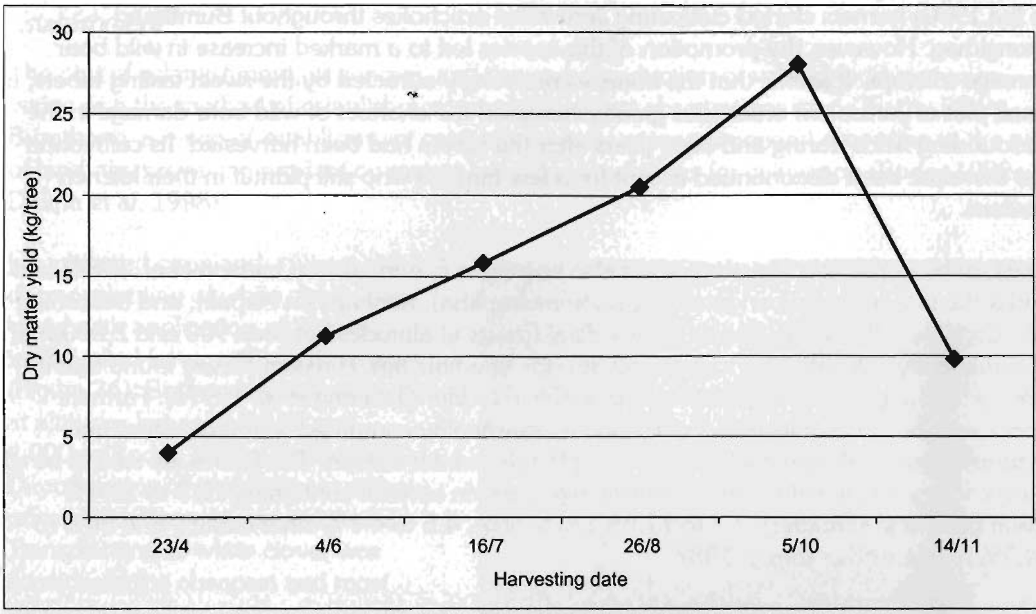

Figure 34: Effect of harvesting date on the dry matter production of willow trees

GAFRC (Grassland and Associated Fodder Research Centre) Bumthang between 1980 and 1985.

Studies carried out during this period included variety trials, fertility management, spacing, intercropping with scarlet bean (*Phaseolus coccineus)*, and the effect of cutting date on the quality of stem biomass and total dry matter yield (Table 40) (Roder 1983c). These experiments found that for Jerusalem artichokes:

- cultivation is easy, thanks to strong weed suppression and the absence of pests and diseases;
- dry matter yields ranged from 10-15t ha^{-1};
- varieties varied in yield, keeping quality, and tuber form - the variety with the highest tuber yield (variety 36-64) had the poorest keeping quality; and
- the highest dry matter yields were obtained when the stems were harvested immediately before they turned yellow, towards the end of September.

Intercropping studies with scarlet bean were inconclusive.

Table 40: Effect of harvesting date on dry matter yield and quality of Jerusalem artichokes *(Helianthus tuberosus)*

Harvesting date	Dry matter yield (t ha^{-1})			Quality of above ground biomass (% of dry matter)		
	Stem	Tuber	Total	Crude protein	Digestible P[1]	Crude fibre
6 June	6.1	0.6	6.7	7.8	1.1	21.6
31 August	9.0	3.5	12.6	7.4	1.4	17.6
19 September	6.9	8.1	15.0	5.0	1.0	24.4
15 November	2.5	7.6	10.2	4.0	0.5	29.6

[1]Pepsin-HCl digestible protein

Source: Roder 1983c and unpublished data by the authors

In the 1980s farmers started cultivating Jerusalem artichokes throughout Bumthang dzongkhag. However, the promotion of this species led to a marked increase in wild boar damage to crops. It seems that the boars were strongly attracted by the sweet tasting tubers; a small plot of Jerusalem artichokes greatly increased the chances of wild boar damage in the surrounding fields during and even years after the tubers had been harvested. Its cultivation has therefore been discontinued except for a few farmers who still plant it in their kitchen gardens.

Ficus roxburghii – This Ficus species is also known as *F. auriculata* (Grierson et al. 1984) and under the local names chongmashing (in Sharchopkha), nebharo (in Nepali), and bakushing (in Dzongkha). It is widely found in broadleaf forests at altitudes between 900 and 2,000m. It is traditionally cultivated for fodder and also for its edible figs. A recent survey found that it was by far the most widely cultivated type of tree fodder (Tshering et al. 1997a). Farmers preferred it because of its high yield, good fodder quality compared with most other tree fodders (Figure 35), and availability during the dry winter season. The leaves are said to be of a satisfactory palatability with a relatively high protein content containing 12.3 to 13.4% crude protein (dry matter), 7.7 to 17.8% crude fibre, 4.5 to 4.7% ether extract, and 50.0 to 64.9% N-free extract (Singh 1982).

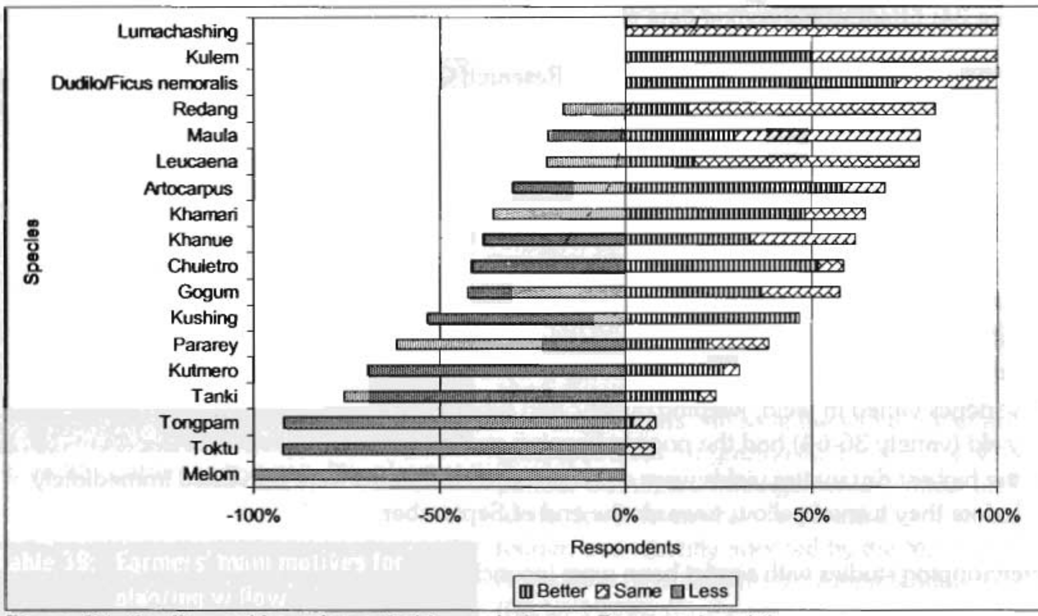

Figure 35: Quality ranking of tree fodders relative to *Ficus roxburghii*

In spite of its importance, only limited research has been carried out on this species. Ongoing activities are focusing on nursery propagation techniques and quantifying variability within population for yield and fodder quality parameters (RNR-RC Jakar 1996b).

Research under 'Production management and treatment practice'

Research under the broad heading of 'Production management and treatment practice' (of fodder) includes the areas of establishment, soil fertility management, legume inoculation, grazing and cutting management, fodder preservation, winter feed, and seed production. Of these, soil fertility management has received the most attention.

Establishment

The cost of establishment, its success, and the early production of seeded fodder species varies with the method of establishment used. Based on observations made by the RDP Bumthang, a range of establishment methods have been recommended according to the type of land, the prevailing production system, and the possibilities for cultivation (Roder 1982c; Dukpa et al. 1998).

Uncultivated grassland – Direct sowing or transplanting of white clover combined with application of P were investigated for uncultivated grassland (Figure 36). Both methods were tested at altitudes between 2,600 and 4,000m (Roder 1982c; Roder 1983c). Direct sowing of grass species without prior cultivation was not successful. Transplanting of white clover was considered the cheapest and most successful method for the improvement of permanent grasslands. Transplanting of lotus and crown vetch *(Coronilla varia)* has also been recommended (Roder 1981a).

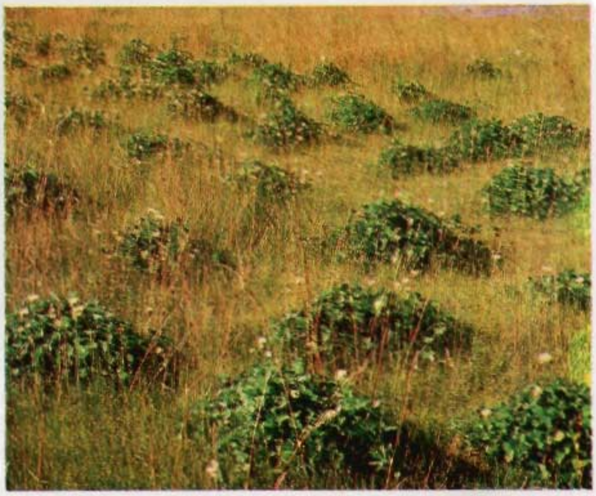

Figure 36: Establishing white clover through transplanting (Lebey, 3,000m)

Cover crop for cultivated fields – Buckwheat, maize, millet, barley, and wheat are all recommended as cover crops for establishing legume-grass mixtures (Roder 1983b). In the farming system common in Bumthang, sweet buckwheat has proved to be the best option. Seeds of the legume and grass species are sown at the same time as the buckwheat. Good seed bed preparation, the time of planting, the short growing period, and limited shading of the cover crop, all combine to make buckwheat an excellent cover crop for the establishment of grass and legume species. In other regions, maize and millet have been found to be the best options for establishing fodder species. In this case the seeds need to be broadcast immediately after the last weeding of the main crop.

Seeding into buckwheat has become the most widely practiced establishment method in higher elevation temperate areas where buckwheat is an important traditional crop. In other areas, fodder species are frequently seeded without a companion crop. This results in high labour costs, heavier weed competition, and frequent failures or else sub-standard stands of the fodder species. The increasing emphasis on the integration of fodder production with field crops and horticulture systems (RNR-RC Jakar 1996a), and the use of fodder species for mulching and soil conservation, has meant that there is a need to develop establishment methods for these systems. Furthermore, the cost of seed to cover one hectare with a white clover, stylo *(Stylosanthes guianensis)*, or desmodium *(Desmodium intortum)* based legume grass mixture is in the range of Nu 1,200-5,000 (approximately US$ 30-125) depending on the seed rate and the source of seed (Dukpa et al. 1998). This is a substantial investment, at present fully paid through subsidies. With the likely reduction of government subsidies for seeds, it will be important for farmers to optimise the success of establishment.

A series of establishment studies using relay seeding in wheat, maize, or rice was initiated in 1996 with the objectives of (1) validating earlier recommendations; (2) evaluating the possibility of relay seeding selected fodder species in to wheat, maize, or rice crops; and (3) quantifying the effect of planting date on establishment success. The results are summarised in Table 41. They showed that

- in all of Bhutan's major cropping systems, fodder and green manure species can be established by broadcast seeding in the particular crop (Figure 37);
- early seeding gives better establishment (Figure 38) – but is often not possible due to weeding requirements and concerns regarding competition with the main crop;
- wheat as a companion crop can only be recommended with spring sown wheat, or where wheat is sown or drilled in lines combined with weed control.

Figure 37: Establishing subtropical legumes by relay seeding in maize

Further studies are required in maize and rice systems to quantify the potential dry matter production of forages and the effect of legume cover on moisture, nutrient, and weed dynamics. In rice systems, the main challenge is the identification of suitable species for particular locations and cropping systems. Studies are needed to (1) evaluate planting date, moisture, and location interactions, and (2) quantify potential biomass production, effects on rice yields, and economic benefits.

Table 41: Relay seeding in field crops - summary of individual studies

Companion crop	Location	Elevation (m)	Species[1]	Planting dates (no.)	Density (plants per m^2)	Most promising species[1]
Wheat	Wangduecholling (Bumthang)	2,680	1,2,3,4,14	2	53	none
Maize	Chamkhar (Bumthang)	2,700	1,2,3,4,5,14	3	114	3, 5 (crimson clover, hairy vetch)
Maize	Sanglajong (Zhemgang)	900	6,7,15,16	2	8	6, 7 (greenleaf desmodium, stylo)
Rice	Bhur farm (Sarpang)	300	2,3,4,5,8,9, 10,11,12,13	1	13	12 (Wynn cassia)

[1] 1 – white clover (*Trifolium repens*), 2 – red clover (*T. pratense*), 3 – crimson clover (*T. incarnatum*), 4 – sweet clover (*Melilotus officinalis*), 5 – hairy vetch (*Vicia villosa*), 6 – greenleaf desmodium (*Desmodium intortum*), 7 – stylo (*Stylosanthes guianensis*), 8 – *Trifolium rueppellianum*, 9 – berseem (*T. alexandrinum*), 10 – *Lablab purpureus*, 11 – *Aeschynomene americana*, 12 – Wynn cassia (*Chamaecrista rotundifolia*), 13 – *Vigna parkeri*, 14 – Italian ryegrass (*Lolium multiflorum*), 15 – molasses (*Melinis minutiflora*), 16 – ruzi grass (*Brachiaria ruziziensis*)

Source: Dukpa et al. 1998; RNR-RC Jakar 1997a

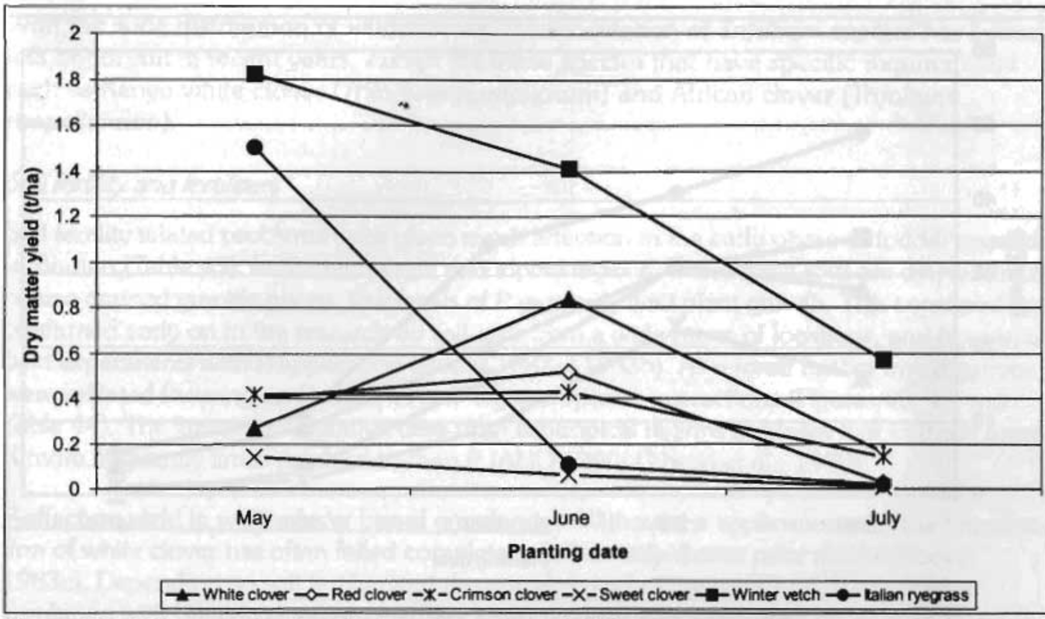

Figure 38: Effect of planting date on dry matter yield in temperate maize system

Establishment of perennial pasture after harvesting potatoes – Potato is an important crop in many temperate regions of Bhutan. Studies were carried out over two years and in two locations to evaluate the effect of planting date on the establishment of lotus, white clover, and hairy vetch *(Vicia villosa)* mixed with Italian ryegrass when planted after a potato harvest (Roder et al. 1991). The studies found that

- potato fields provide excellent seed bed conditions for the broadcast seeding of fodder species;
- the broadcast seeding of white clover, lotus, and hairy vetch can be extended as late as mid-September (Figure 39); and
- residual nitrogen from fertiliser and manure applied to potato crops favours the establishment and early growth of grass species, thus reducing clover dominance.

High elevation bamboo-dominated pasture – Studies were initiated in 1995 and 1996 on establishment method, species performance, and P interaction in a bamboo dominated, wet pasture at 3,500m in Shinkhar Ura (RNR-RC Jakar 1997a). The intermediate results indicate that

- lotus and white clover show some promise in this environment;
- direct seeding or transplanting is superior to digging and/or burning field preparation; and
- production of introduced species is poor, possibly due to micro-nutrient deficiencies.

Inoculation of legumes

Inoculation with *Rhizobium* is necessary for most species of temperate legumes (Table 42). Initial introductions of *Trifolium* and *Medicago* species in Bumthang failed because the appropriate inoculum was not available (Roder 1983d). Over the years a number of inoculation studies have been carried out to

- quantify the effect of inoculation on various legume species (AHD 1990; Gibson 1989b);
- test inoculation methods (Dorji and Roder 1980; Roder 1983d; Gibson 1989b); and
- test the quality of inoculum (AHD 1990).

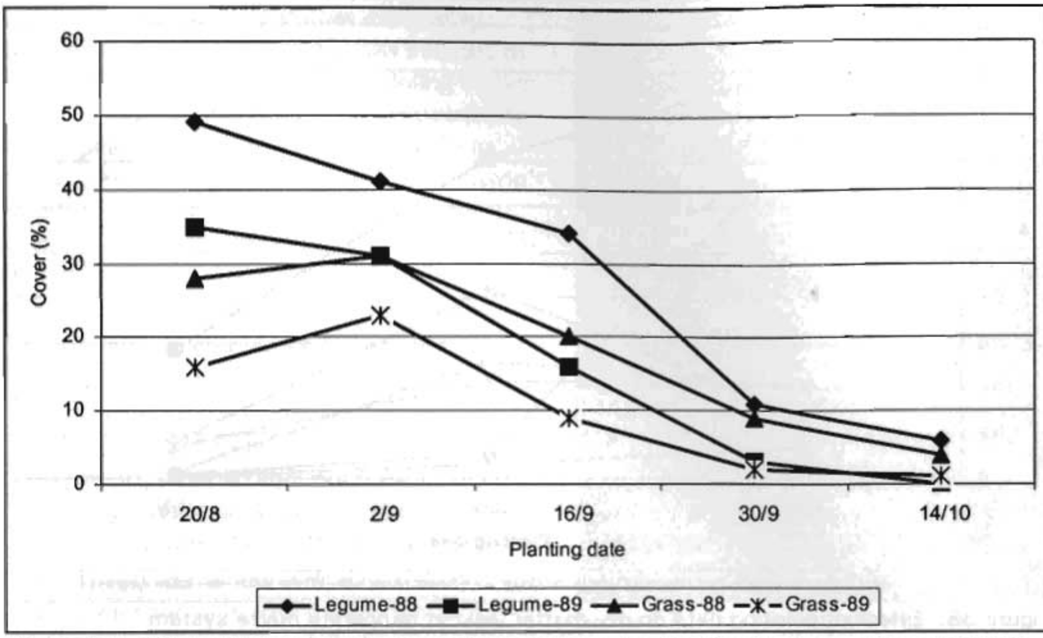

Figure 39: Effect of planting date on cover of legume species (Legume = average of white clover, lotus, and hairy vetch) and Italian ryegrass (Grass).

Table 42: Inoculation requirements for temperate fodder legumes

Inoculation requirements	Species	Reference
No survival or extremely poor growth if not inoculated	All *Trifolium* species[1]	Roder 1983c; 1983d
	All *Medicago* species	Roder 1983d
	All *Melilotus* species	Roder 1983d
	Robinia pseudoacacia	Roder 1983c
	Lotus pedunculatus	Roder 1983e
	All *Lupine* species except *L. mutabilis*	Roder 1983e
Show no or limited response to inoculation but require observation	*Lotus corniculatus*	Roder 1983d
	Onobrychis species	Authors[2]
	Lathyrus species	"
No information available on the requirement under Bhutanese conditions	*Astragalus* species	"
	Coronilla varia	"
Nodulate freely with native strains	*Vicia* species	Roder 1983d
	Lupinus mutabilis	Roder 1983e
	Pea	Authors[2]

[1] *T. semipilosum* and *T. ruepellianum* are highly specific, ordinary *Trifolium* strains are not suitable; [2] unpublished observations by authors of this review

Inoculation is less important for subtropical species as they are generally less specific in their requirement for a particular rhizobia strain. Several studies have found no significant response of subtropical legumes to inoculation (Gibson 1989b).

With the wide distribution of white clover, the inoculation of *Trifolium* species has become less important in recent years, except for those species that have specific requirements such as Kenya white clover (*Trifolium semipilosum*) and African clover (*Trifolium ruepellianum*).

Soil fertility and fertilisers

Soil fertility related problems were given much attention in the early phase of fodder research in Bhutan (Table 43). In the temperate and alpine regions, where most soils are derived from coarse-grained granitic gneiss, low levels of P generally limit plant growth. This constraint was confirmed early on in the research by soil tests from a wide range of locations, and from initial field experiments with P-application (Roder 1982a; 1983b). As a result further investigations were initiated focusing on P and P-N or P-legume species interactions (Figures 40, 41 and Table 44). The limited quantitative data from subtropical regions indicates that in those areas K more frequently limits production than P (AHD 1990; Gibson et al., 1990).

<u>P-effect on yield in white clover based grasslands</u> – Without the application of P, the introduction of white clover has often failed completely, or has only shown poor results (Roder 1983c). Depending on soil fertility and the management of the grassland, P application combined with the introduction of white clover increased the dry matter production by up to 30 times as compared to control plots (Table 44, Figures 40 and 42). The introduction of white clover with the application of P was found not only to increase yield but also simultaneously to increase the quality of the dry matter (Roder et al. 1997b).

Results from Kidiphu and Laya suggest that the expected gain in dry matter production through P application and white clover introduction decreases with altitude (Gyamtsho 1996; Roder 1983c). Similarly the potential to increase grassland production decreases with increasing elevation (Dunbar 1979; Harris 1987; Roder 1983c and 1990a).

In a multi-locational trial (Dorji and Dukpa 1992), the application of 26 kg of P increased the average dry matter yield by 39% whilst the application of 1.5t manure ha^{-1} increased yields by an average of 29%. This was tested at seven locations over three years (Figure 42). The comparatively low yield effects of P and manure application in this study were attributed to the experimental fields either being nashing (cultivated wetland) or pangshing (shifting cultivation land) fields, which already had relatively high levels of soil fertility. In most fertiliser trials the biomass produced was harvested by cutting and removing it from the plots rather than testing under grazing conditions, in which case there would have been a fertility input from animal waste. In a grazing study, an increase of P from 9 to 26 kg ha^{-1} increased the dry matter yield over four years by 209% (Roder 1983c).

<u>P-fertilisers</u> – The phosphate fertilisers available in Bhutan during the 1970s and 1980s were tricalcium phosphate (rock phosphate), mono-tricalcium phosphate (superphosphate and rock phosphate mixed), and at a later stage single superphosphate. Rock phosphate has been widely recommended because of its supposedly better effect in acid soils. However, initial applications of rock phosphate showed a very poor response, therefore several fertiliser studies were initiated to quantify the effect of these fertilisers (Gyamtsho 1986; Roder 1983c). In these studies rock phosphat, even if used repeatedly over several years, was found to have little effect on dry matter yields (Gyamtsho 1986; Roder 1983c). Based on the results of these studies, the promotion of both types of rock phosphate was discontinued in the extension programmes.

Table 43: Soil fertility studies in permanent grassland systems		
	Location	**Reference**
Subtropical		
P-effects	Pemagatshel	Gibson et al., 1990
K-effects	Pemagatshel, Samtse	AHD 1990; Gibson et al. 1990
Trace elements	Pemagatshel, Samtse	AHD 1990; Gibson et al. 1990
P-effect for establishment	Namthay	Dorji and Dukpa 1992
N-effects	Samtse	AHD 1990
Temperate		
Fertiliser effect for establishment	Batbalathang, Phubjikha	ARC 1989; Roder 1983c; RNR-RC Jakar 1997a
Dolomite effect for establishment	Phubjikha	ARC 1989
P-effects, P-level	Batbalathang, Nationwide, Mongar, Wabthang	AHD 1990; Dorjee 1989; Dorji and Dukpa, 1992; Gyamtsho 1986; Roder 1983c
P-fertilisers	Batbalathang, Lebay, Mongar	AHD1990, Roder 1983c
P-effects under grazing	Batbalathang	Gyamtsho 1986; Roder 1983c
P-legume species interactions	Batbalathang	Gyamtsho 1986; Roder 1983c
Manure	Batbalathang, Nationwide, Wabtang	AHD1990; Dorjee 1989; Dorji and Dukpa, 1992; Gyamtsho 1986; Roder 1983c
Other P sources	Batabalathang	Dorjee 1989; Dorji and Dukpa, 1992; Roder 1983c
N-effects	Batbalathang, Wabtang	AHD 1990; Gyamtsho 1986;
Boron effects	Batbalathang	Gyamtsho 1986; Roder 1983c
Potassium	Batbalathang	Gibson, 1989b; Gyamtsho 1986; Roder 1983c
Lime	Batbalathang	Gyamtsho 1986; Roder 1983c
Sulphur/gypsum	Batbalathang	Dorjee 1989; Gyamtsho 1986; Roder 1983c
Alpine		
P-effects, P-level	Kidiphu, Ura. Laya	Dorjee 1989; Gyamtsho 1986; Gyamthso 1996; Roder 1983c
P-legume species interactions	Kidiphu, Laya	Gyamthso 1996; Roder 1983c
Manure	Kidiphu	Roder 1983c
N-effects	Laya	Gyamthso 1996

Alternative sources of P – The limitations on fodder production due to low P availability and the high transportation cost of imported P inputs led to a number of studies being commissioned to evaluate possible alternative sources of P. A number of studies showed promising results with manure (Dorji and Dukpa 1992; Roder 1983c). In contrast, application of ash (from blue pine needles), compost, or blue pine needles did not increase forage yields (Gyamtsho 1986; Roder 1983c).

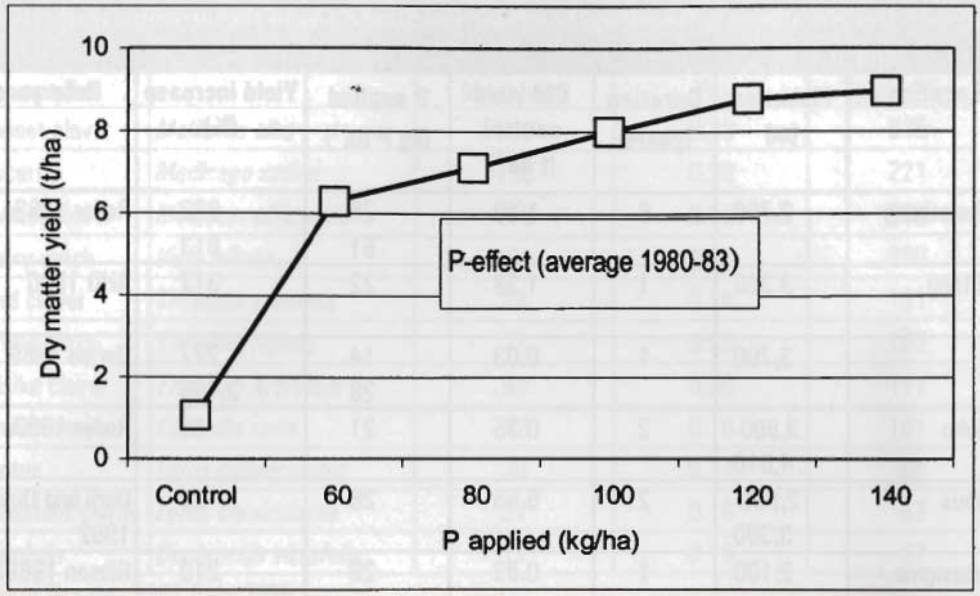

Figure 40: Effect of P on clover/grass dry matter yield in a cut and carry system

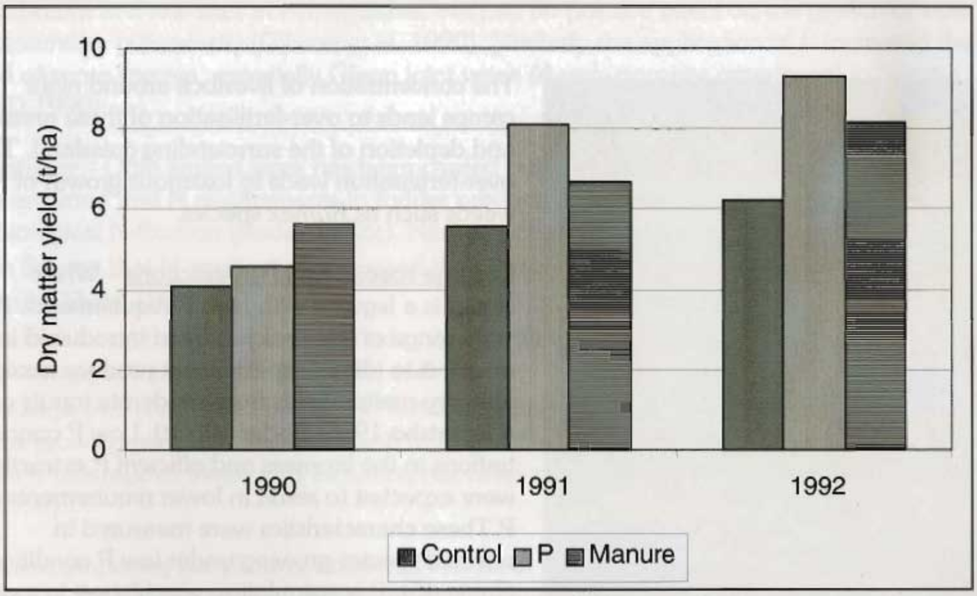

Figure 41: Effect of P and manure on dry matter yield across 7 sites

Locally produced bone meal was used for cattle feed in the 1970s (personal communication by the authors), but the quantities available were too small for large-scale use as fertiliser.

Manure, although produced in substantial quantities, is mostly used for applying to cultivated fields. It is usually collected by housing the livestock during the night or by tethering animals in crop fields. In the traditional production system there is thus a continuous flow of P from grassland to cropland. Manure accumulated in remote areas by migrating herds is often burned and the ash is applied to crop fields.

Table 44: Quantitative data from P application in combination with the introduction of white clover						
Location	**Elevation (m)**	**Duration (years)**	**DM yield control (t ha^{-1})**	**P applied (kg P ha^{-1})**	**Yield increase (%)**	**Reference**
Batbalathang	2,700	6	1.29	26 51	623 813	Roder 1983c
Wabtang	3,300	1	1.38	22	317	AHD 1990
Ura	3,700	1	0.03	14 28	777 3,155	Dorjee 1989
Kidiphu	3,890-4,010	2	0.35	21	49	Roder 1983c
Various	2,600-3,300	2	5.55	26	39	Dorji and Dukpa 1992
Gonpasigma	2,100	1	0.83	29	210	Gibson 1989a
Laya	4,020	3	2.06	21 42	64 64	Gyamtsho 1996


Figure 42: Effect of P application on white clover based mixtures

The concentration of livestock around night camps leads to over-fertilisation of these areas and depletion of the surrounding grassland. This over-fertilisation leads to luxurious growth of weeds such as *Rumex* species.

Legume species and P-interactions – White clover is a legume with high P requirements. A wide range of legumes has been introduced in an effort to identify species that produce acceptable dry matter yields from moderate inputs of P (Gyamtsho 1986; Roder 1983c). Low P concentrations in the biomass and efficient P extraction were expected to result in lower requirements of P. These characteristics were measured in selected species growing under low P conditions (Table 45). P accumulation was highest in sweet clover species (*Melilotus alba* and *M. officinalis*), lucerne, and hairy vetch. Lotus and hairy vetch had the lowest P concentrations in their biomass. These findings, together with observations from screening nurseries and other trials, led to sweet clover, hairy vetch, and lucerne being recommended as alternative legumes with lower P requirement (Gyamtsho 1986; Roder 1983b, 1983c). Unfortunately these studies were discontinued in 1985.

Table 45: P-concentration and P-accumulation by selected legume species				
Legume species	Scientific Name	P-accumulation (mg/plant)	P-concentration (%)	DM yield (g/plant)
Sweet clover	*Melilotus alba*	309	0.20	635
Lucerne	*Medicago sativa*	126	0.23	221
Sweet clover	*Melilotus officinalis*	116	0.16	288
Hairy vetch	*Vicia villosa*	100	0.14	289
Red clover	*Trifolium pratense*	84	0.18	191
White clover	*Trifolium repens*	73	0.28	102
Alsike clover	*Trifolium hybridum*	56	0.20	111
Crown vetch	*Coronilla varia*	47	0.19	101
Lotus	*Lotus pedunculatus*	36	0.14	96
Birdsfoot trefoil	*Lotus corniculatus*	27	0.16	67
Sainfoin	*Onobrychis viciafolia*	11	0.16	27

Source: Gyamtsho 1986; Roder 1983c

P-effects in subtropical regions – Application of P was found to increase the yield of greenleaf desmodium at a few sites in Pemagatshel, but had no positive effect on the growth of stylo (*Stylosanthes guianensis)* (Gibson et al. 1990). Similarly the application of P increased the yield of some species, especially Glenn joint vetch *(Aeschynomene americana)* in Samtse (AHD 1990).

N-fertiliser – Only limited work has been carried out to evaluate the effect of N-fertilisers as it was assumed that N requirements in fodder production systems should primarily be covered by biological N-fixation (Roder 1982c). Nitrogen studies have found

- in Samtse that N application increased the yield of tropical grass species by 62% (Murtagh and Chhetri 1985);
- in Wobthang that N application had only a limited effect on dry matter yields of white clover-grass mixtures (AHD 1990); and
- in Laya (4,010m) that 100 kg of N fertiliser applied in two split doses at the beginning of the growing period in May/June and in August/September increased dry matter yield by 46% (average of treatments including native species, white clover, and lotus) (Gyamtsho 1996).

Studies comparing the effect of different N levels or intercropping with scarlet bean on tuber and stem dry matter yields of Jerusalem artichokes were not conclusive (Gyamtsho 1986; Roder 1983c).

Other nutrients – Other nutrients evaluated in temperate regions include potassium (K), boron, calcium, and sulphur. The application of these nutrients was found to have no significant effect on legume establishment (ARC 1989) or dry matter yields (Gyamtsho 1986; Roder 1983c). In contrast, in Pemagatshel at several locations increased levels of K or trace elements were found to be necessary for the establishment of shrubby legume species and K and trace element effects were found on white clover, lotus, African clover, and greenleaf desmodium at some sites (Gibson et al. 1990). Further studies are needed to differentiate the effects of K and trace elements. Fertiliser treatments generally had no positive effect on the growth of stylo. K and/or trace element applications also increased the dry matter yields of some species in Samtse (AHD 1990) and lime increased the growth rate of *Leucaena leucocephala*.

Cutting and grazing management

Only limited work has been carried out into the effects of cutting and grazing management on native or improved grasslands (Roder 1990a). A grazing trial with set stocking rates of 22.2, 14.5, and 7.4 ewes per hectare was carried out in Wabtang, Tang in 1989 (AHD 1990). However, the different stocking rates were found to have no effect on dry matter production of pastures and no significant effect on wool production per animal. Higher stocking rates, however, did result in better utilisation of the pasture and higher wool yields per area. In an experiment initiated in 1995, P-application and cutting intensity were found to have a strong effect on the yield and botanical composition of a white clover and grass mixture (RNR-RC Jakar 1997a) (Tables 46 and 47). The contribution of clover to the biomass yield and the quality of the biomass was substantially increased by P-application. The contribution of exotic grass species, mostly cocksfoot, increased in all treatments, probably due to a change from poor management (continuous grazing) to a system with grazing-free rest periods.

Table 46: Effect of fertiliser and cutting interval on fodder quality

Treatments		Composition (%)		
Cuts	Fertiliser	CP[1]	NFE	CF
2	Control	8.5	52.6	30.6
2	Phosphate	15.1	44.1	29.3
4	Control	15.3	43.1	30.1
4	Phosphate	26.2	40.2	22.8

[1] CP = crude protein, NFE = nitrogen free extract; CF = crude fibre
Source: RNR-RC Jakar 1997a

Table 47: Effect of fertiliser treatment on dry matter yield

Treatment	DM yield (t ha^{-1})		Botanical composition (%)[1]	
	1995	1996[2]	Clover	Grass
Cutting intervals				
2 cuttings	7.9 A	5.8 A	35 A	55 A
4 cuttings	9.5 A	11.8 B	41 A	57 A
Fertiliser				
Control	6.9 A	7.7 A	8 A	78 A
P	8.4 B	8.4 A	56 B	43 B
P & N	10.7 C	10.2 B	50 B	48 B
Coefficient of variation	15.6	9.4	45.2	34.3

[1] Observations from 1st cut in 1997; [2] numbers followed by the same letter are not significantly different at the 0.05 probability level
Source: RNR-RC Jakar 1997a

Winter fodder

The need for increased winter fodder production and higher quality of winter fodder has always been awarded high priority (Roder 1998c). Increased production of winter fodder is indirectly addressed through the work discussed under genetic evaluation and improvement. This section reviews work carried out specifically addressing improvements in winter fodder through management interventions (Table 48).

<u>Fodder conservation</u> – Methods of fodder conservation, principally hay and silage making, were evaluated in the early phases of the RDP fodder development programme. Due to the high labour requirements, farmers have not adopted silage making. Following examples from

Europe, hay making on different types of drying racks was tried but this also met with little success (AHD undated, printed in 1978; Roder 1980, 1983b, 1983d, 1998c). The high rainfall during the main growing season makes hay and silage making difficult. Furthermore, the high labour requirement for transporting plant material that has a high water content, makes silage making uneconomic for most farmers (Roder 1998c). Silage making is only feasible with a certain level of mechanisation. For the conditions prevailing in temperate Bhutan, deferred grazing (standing hay) may be the most appropriate form of fodder conservation.

Table 48: Studies aimed at increasing winter fodder availability, quality, and economic viability

Type of study	Locations	References
Fodder conservation with drying racks	Batbalathang	Roder 1983d
Fodder conservation with pit silos	Bumthang district	Roder 1983d
Fodder conservation in the field	Batbalathang	Roder 1998c
Arable fodder crops	Bumthang dzongkhag	Roder 1983c; RNR-RC Jakar 1997a
Tree fodder species	National	Roder 1983c; Tshering et al. 1997
Preservation of tree fodder species	Serbithang, Bumthang	Roder 1983c; Premasiri 1988

The feasibility of keeping standing hay was evaluated by keeping grass/clover biomass in fields for grazing between December and February (Roder 1998c). It was found that the total dry matter yield was not affected by harvesting date (Figure 43) although the dry matter content decreased gradually till January. January snowfall increased the moisture of the legume component and decreased the proportion of the legume in the total dry matter yield. Although the legume component decreased over time, the overall quality was not significantly different between November and February harvests (Table 49). If there is a loss in quality, as suggested by the increase in crude fibre of 13%, it would be below the level of losses normally associated with hay or silage making. The method of grazing standing fodder during the dry

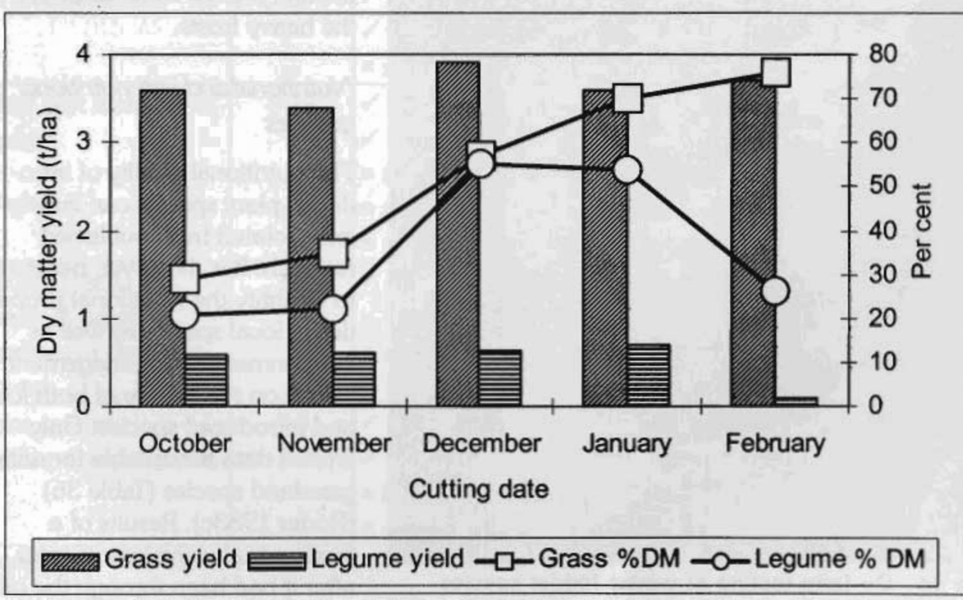

Figure 43: Effect of harvesting date on dry matter yield and content of standing hay

winter period has the advantage of reducing labour requirements for harvesting, feeding, and transport of manure.

Roder (1983c) reported that dried willow leaves were not accepted by cattle. They were, however, accepted when made into silage (Premasiri 1988).

Table 49: Effect of harvesting date on quality of standing hay

Parameter	Composition (% DM)	
	Harvest 25 Nov	Harvest 25 Feb
Crude protein	7.0 ± 2.1	9.1 ± 2.5
Crude fibre	24.6 ± 0.3	28.2 ± 2.3
Ether extract	1.4 ± 0.1	0.8 ± 0.1
Nitrogen free extract	57.8 ± 1.7	53.9 ± 4.2

Source: Roder 1998c

Crops for winter feed – The use of swede *(Brassica napus)*, hairy vetch, rye *(Secale cereale)*, willow, and other species, together with new management methods such as standing hay were recommended to increase the availability of winter feed (Table 50, Roder 1983c, 1983c, 1998e; RNR-RC Jakar 1997a). However, these innovations have not yet been adopted by Bhutan's farmers (Roder 1998c). Further investigations are needed to confirm earlier findings and refine recommended technologies.

The crops that have been most researched are Jerusalem artichoke, swede, hairy vetch, and rye. RNR-RC Jakar (1997a) reports further evidence of the high potential of swede and hairy vetch (Figure 44). Under Bumthang conditions, appreciable dry matter yields can be expected if these species are planted in late summer after the harvesting of potatoes. When planted in early August, dry matter yields were 12.7 t/ha for a rye and hairy vetch mixture, 9.7 t/ha for swede, 4.9 t/ha for turnip, 5.4 t/ha for lupine *(L. angustifolius)*, and 3.3 t/ha for sweet buckwheat. Yields declined substantially with later planting dates (Table 51, Figure 45). Sweet buckwheat is the only crop at present used by farmers for producing winter fodder (RNR-RC Jakar 1997a). It was not possible to keep the above crops in the field for extended periods over the winter months. Dry matter yields for most species were the same whether harvested in early November or early January. After this date all species except for rye, hairy vetch, and Italian ryegrass were destroyed by the heavy frosts.

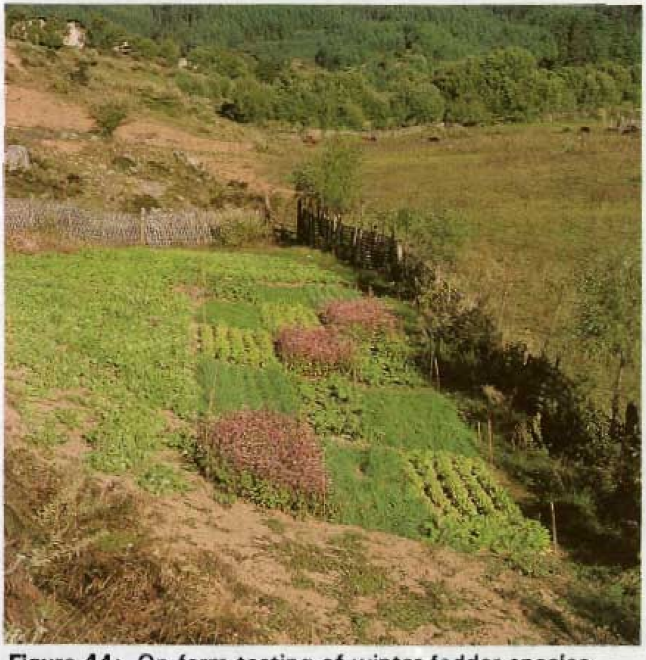

Figure 44: On-farm testing of winter fodder species (Tang, 2,700m)

Nutritional and anti-nutritional qualities

The nutritional quality of introduced plant species can largely be extrapolated from published research. It is, however, necessary to quantify the nutritional properties of local species as well as environment and management effects on the quality of both local and introduced species. Only limited data is available for native grassland species (Table 36) (Roder 1983c). Results of a feeding trial using lemon grass after it had been through the oil

Table 50: Crops evaluated for winter feed production

Crop	DM yield (t/ha)	Positive (✓) and negative (×) properties	Refs[1]
Maize *(Zea mays)*	5-12	✓ high yield × requires chopping and conservation × bear and wild boar damage × requires high soil fertility	1
Oats *(Avena sativa)*	3-5	✓ traditionally used as feed × requires high soil fertility	1
Buckwheat *(Fagopyrum esculentum)*	0.5-2	✓ traditionally used as winter feed × low quality × low yield potential	2
Kale *(Brassica oleracea)*	4-6	✓ high yield, high frost resistance × insect damage, requires repeated insecticide application × requires high soil fertility	2
Swede *(Brassica napus)*	2-5	✓ high yield × needs high soil fertility or N-inputs	2, 3
Turnip *(Brassica rapa var. rapifera)*	2-4	✓ widely used ✓ no pest problems × limited yield potential, needs fertile soils	2, 3
Jerusalem artichokes *(Helianthus tuberosus)*	5-15	✓ high yield × labour for harvest × wild boar problem × needs high soil fertility or N-inputs	4, 2
Hairy vetch *(Vicia villosa)*	3-6	✓ high yield ✓ winter growth, frost tolerant	2, 3
Rye *(Secale cereale)*	3-6	✓ high yield ✓ winter growth, frost tolerant × needs high soil fertility and/or N-inputs	2, 3
Fodder beet *(Beta vulgaris*	6-15	✓ high yield ✓ can be stored till April × needs high soil fertility and/or N-inputs × pest problems × wild boar problems	2, 5
Brassica species *(B.rapa, B. napus, B. pekinensis Raphanus sativus)*	2-3	✓ high yield ✓ frost tolerant × needs high soil fertility or N-inputs	2
Lupine species *(L. albus, L. angustifolius)*	2-6	✓ high protein content ✓ no N input required × limited frost tolerance × requires inoculation	1, 2

[1] References: 1 – Roder 1983e; 2 – Roder 1983c; 3 – RNR-RC Jakar 1997a; 4 – Gyamtsho 1986; 5 – Dorji and Dukpa 1992

Table 51: Effect of planting date on dry matter yields of winter fodder species	
Treatment	**DM yield (t/ha)** [1]
Planting date (average of all species)	
August 2	5.8[A]
August 23	3.4[B]
September 11	1.7[C]
Species (average of all planting dates)	
Swede	6.5[A]
Turnip	2.9[B]
Sweet lupine	2.3[C]
Sweet buckwheat	2.8[B]

[1] Numbers followed by the same letter are not significantly different at the 0.05 probability level
Source: RNR-RC Jakar 1997a

extracting process indicated that this material replaced over 75% of the herbage dry matter with no effect on the intake or milk production when fed to cattle (Bajracharya 1991). Dry matter disappearance of this post-processing plant material was better than from paddy straw or urea treated paddy straw.

Tamang (1987) published extensive analytical data on common fodder sources. The parameters measured included the levels of crude protein, neutral detergent fibre, acid detergent fibre, and rumen degradability (Table 52). Over 30% of the fodder species listed in his publication are tree fodders. This is a very valuable contribution as most of the popular tree fodder species are native species and only limited information is available on their nutritional qualities. Additional analytical data on temperate tree fodders was generated through work carried out in Bumthang (Table 53).

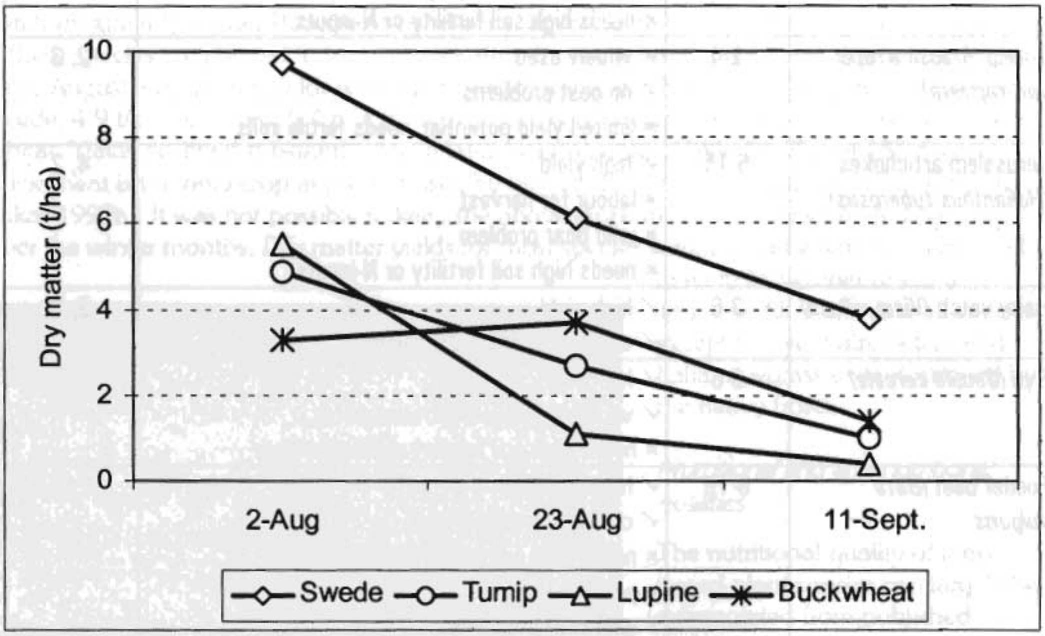

Figure 45: Effect of planting date on dry matter yield of selected winter fodder species

Willow *(Salix babylonica)* is the most studied of the tree fodders. Analytical data are available for leaf samples taken throughout the growing season (Roder 1992; Wangdi et al. 1997). The palatability and nutritional quality have been evaluated in feeding trials with cattle and sheep. These studies confirmed that willow leaves have a high nutritional quality comparable to common forages such as lucerne. The same studies found that willow can be fed to ruminants without any adverse side effects. Leaves harvested in April, May, September, October, and

Table 52: Quality of selected subtropical tree fodder species					
Species	Crude fibre (%)	Crude protein (%)	NDF[1] (%)	ADF[2] (%)	Degradability[3]
Artocarpus lakoocha	24.1	14.7	36.2	23.1	88.9
Erythrina variegata	31.0	7.9	37.9	35.0	85.4
Elaeagnus latifolia	34.2	11.7	60.6	35.4	54.3
Ficus cunia	24.0	10.8	30.0	29.4	86.0
Celtis australis	30.4	13.1	41.4	35.4	65.0
Litsea polyantha	24.8	15.9	55.7	42.7	52.0
Ficus roxburghii	33.3	10.0	49.3	45.3	53.5
Salix babylonica (willow leaves)	38.1	10.3	48.0	14.3	75.9
Rice straw (urea treated)	39.2	7.1	75.6	59.8	63.8

1 Neutral detergent fibre; 2 acid detergent fibre; 3 rumen degradability after 48 hours incubation in fistulated animals
Source: Tamang 1987

November had crude protein contents of 25, 22, 17, 16, and 11%, and crude fibre contents of 12, 16, 15, 15, and 22%, respectively (Roder 1992). Voluntary intake of willow leaves and animal performance was high with sheep and cattle (Table 54). Voluntary intake was much lower with other traditional tree fodders used in temperate Bhutan (Table 55). In terms of rate of digestion in the rumen, willow was far superior to other tree leaves that are commonly used as feed. Digestion rates for willow, black locust *(Robinia pseudoacacia)*, *Litsea polyantha* leaves, and mixed hay were 78, 44, 31, and 31% after 24 hours of incubation, and 85, 65, 54, and 56% after 48 hours of incubation, respectively (Bajracharya 1990).

Table 53: Quality of selected temperate tree fodder species			
Species	Crude fibre (%)	Crude protein (%)	Digestible protein (%)[1]
Willow *(Salix babylonica)*	14.8	16.4	10.5
Evergreen oak *(Quercus semecarpifolia)*	30.9	9.7	1.2
Populus robusta	20.6	9.2	0.8
Local *Populus* sp	24.0	7.5	0.4

1 Pepsin-HCl soluble protein
Source: Roder 1992

Table 54: Willow intake and live-weight gain of two ruminants			
Animal type	Voluntary Intake (g DM/$W^{0.75}$)	Live-weight gain (g/day)	Reference
Bull	78	330	Roder 1992
Sheep	85	64	Bajracharya 1990

Seed production

The seed production potentials of introduced species were generally assessed in the early stages of germplasm evaluation (Table 56) (Roder 1983c), and only species that produced seed were advanced in the testing programme. White clover was an exception to this due to its high potential for improving permanent grassland and its potential for vegetative multiplication.

Table 55: Intake of tree fodders by large ruminants				
Species	**Month**	**Duration (days)[1]**	**No. of animals**	**DM intake (kg/day)**
Quercus semecarpifolia	April	5	3	2.8
Quercus semecarpifolia	March	11	4	1.8
Populus robusta	October	12	2	3.4
Populus (local sp)	October	5	2	1.9

[1] Duration of feeding the particular fodder in days
Source: Roder 1992


Figure 46: Harvesting tall fescue seed

Several institutions and projects took up fodder seed production (Figure 46). The ambitious targets for fodder development starting from the Fourth Plan period (1976-81) required relatively large quantities of seed, so seed production was shifted to farmers' fields. Harris (1986) reviewed the achievements in temperate seed production, and attributed the success in the seed multiplication programme to the research carried out in the early 1980s.

Cocksfoot and some of the most promising legumes, especially lucerne, red clover, lotus, and greenleaf desmodium, were not included in the initial government extension programmes because of difficulties in large-scale seed multiplication. A number of research efforts focused on seed production technologies for these species. Some of these efforts had substantial impacts on the grass seed multiplication programme. A species-wise summary of the results is given in Table 56.

Cocksfoot seed production – The seed yield of cocksfoot varieties in introduction nurseries, using plots of less than $10m^2$ was found to range from 29 to 333 kg ha^{-1} in 1980 and from 17 to 446 kg ha^{-1} in 1981 (Roder 1983c). The varieties with the highest dry matter production - G 16 and Appanui - had the lowest seed yields, however. The seed yields of these varieties was still very poor when plants were established by drilling in rows 40 cm apart (Roder 1983c). It was clear that cocksfoot seed, especially for the selected varieties, could only be produced commercially if the production method could be improved. A series of experiments was initiated in 1981 focusing on spacing, N-fertiliser, and planting dates (Roder 1983c) (Figure 47). The results of these studies showed that for cocksfoot:

- insufficient spacing resulted in poor seed production;
- transplanting seedlings raised in a nursery was the best way to establish a seed production stand;

Table 56: Seed yields reported from selected individual species					
Species		Reference[1]	Entries/ years[2]	Yield (kg ha^{-1})	
				Average	Range
White clover	*Trifolium repens*	1, 2	5/1	12.1	2.7-60
Red clover	*Trifolium pratense*	1, 2	11/2	5.7	0.4-24
Birdsfoot trefoil	*Lotus corniculatus*	1, 2	6/1	5.7	0.8-16.7
Lotus	*Lotus pedunculatus*	1, 2	5/1	78.2	18.8-200
Greenleaf desmodium	*Desmodium intortum*	5	1/1	122	1.4-23
Silverleaf desmodium	*Desmodium uncinatum*	5	1/1	330	0.6-78
Italian ryegrass	*Lolium multiflorum*	1, 2	6/2	1407	654-1814
		3	4/1	531	215-1076
Cocksfoot	*Dactylis glomerata*	1, 2	12/2	146	17-446
		3	6/1	46	30-90
Tall fescue	*Festuca arundinacea*	1, 2	4/2	391	138-583
		3	1/1	1410	-
Perennial ryegrass	*Lolium perenne*	1, 2	7/2	585	145-1085
		3	5/1	648	377-1238
Timothy	*Phleum pratense*	1, 2	4/1	95	-
Meadow fescue	*Festuca pratensis*	1, 2	4/2	621	323-1071
		3	2/1	28	23-32
Red fescue	*Festuca rubra*	2	2/2	423	160-910
		4	1/1	1280	1170-1390
Ruzi grass	*Brachiaria ruziziensis*	6	1/1	147	104-233

[1] References: 1 - Roder 1982c; 2 - Roder 1983c; 3 - Dorji 1982a; 4 - Luthi 1998; 5 - Tshering et al. 1997b; 6 - Pradhan 1990; [2] number observed over number of years, 5/1 indicates 5 entries with observations over 1 year

- there was no significant effect of row spacing;
- inter-plant spacings of 10, 15, 20, and 25 cm had no effect on yields;
- white clover is a poor substitute for N-fertiliser application in grass seed production (Gyamtsho 1986); and
- planting is possible until late September (ARC 1990).

Figure 47: Study evaluating spacing effect on cocksfoot seed production

Desmodium seed production – Studies were initiated in 1996 to evaluate the effect of location on flowering and seed production of greenleaf *(Desmodium intortum)* and silverleaf *(D. uncinatum)* desmodium, and the effect of cutting management, support, planting density, and irrigation regimes on greenleaf

Table 57: Effect of location on flowering and seed production of silverleaf and greenleaf desmodium

		Location		
		Bhur	Lingmethang	Khothakpa (Pemagathsel)
Altitude		200m	640m	850m
Flowering date	silverleaf	-	24 Oct	23 Oct
	greenleaf	-	24 Nov	21 Nov
Harvesting date	silverleaf	12 Nov-3 Dec	27 Dec	24 Dec
	greenleaf	-	29 Jan	26 Jan
Average seed production	silverleaf (g/m^2)	0.6	78	21
	greenleaf (g/m^2)	-	23	1.4

Source: Tshering et al. 1997b

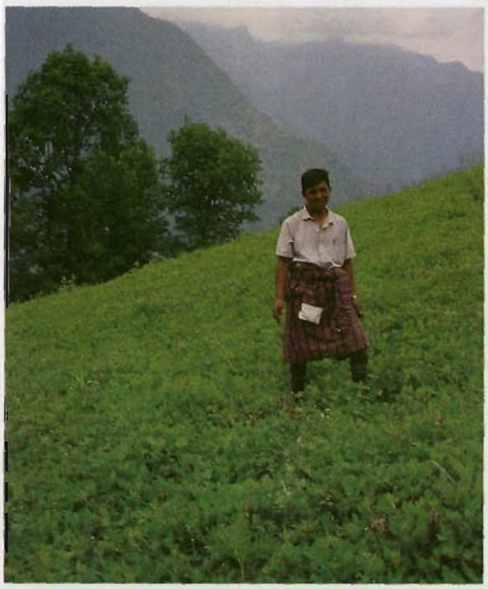

Figure 48: Desmodium seed production study, Wangdugang (1,590 m)

Table 58: Effect of location and management on flowering, pod formation and seed production of greenleaf desmodium

Parameter		Flowering ($no./m^2$)	Pods formed ($no./m^2$)	Seed yield (g/m^2)
Location/Elevation				
Wangdugang	1,590m	64	44	3.2
Dhakphai	1,490m	44	34	7.0
Birthay	800m	29	13	1.1
Tama	1,560m	16	1	-
Tama	1,580m	21	7	-
Zurphey	1,150m	64	-	-
Cutting[1]				
No cutting		43^A	25^A	5.6^A
May cutting		44^A	23^A	3.9^A
June cutting		31^A	12^A	1.7^A
Support[1]				
No support		28^A	15^A	3.6^A
Support[2]		50^B	24^B	3.9^A
Coefficient of variation (%)		22.6	39.0	41.3

[1] Numbers followed by the same letter are not significantly different at the 0.01 probability level; [2] support with 1m high bamboo sticks

desmodium seed production (Tshering et al. 1997b). The results are summarised in Tables 57 and 58.

The most important findings from these studies were that:

- Bhutan has excellent conditions for the production of both greenleaf and silverleaf desmodium (Figure 48);
- the time of flowering, and the number of flowers per area was not influenced by altitude, or cutting and spacing treatments - flowering started almost simultaneously at all locations;
- support with bamboo sticks increased flower and pod density but not seed yield;

- seed yields may be increased through the manipulation of plant density, the exclusion of competition effects from grasses, the control of insect pests, and, where available, timely irrigation.

Integrated studies

In addition to providing more food for raising animals, improved forage production is expected to result in a multitude of benefits for any particular farming system The expected benefits include:

- improvements in soil fertility and soil and water conservation;
- weed suppression and reduced need of labour for weed control in fruit and timber plantations;
- optimisation of economic returns from marginal crops and grasslands by combining fodder and timber production; and
- synergistic effects on annual crops and perennials cultivated in association with fodder plants.

A number of studies have attempted to quantify these effects (Table 59). Most of these studies have been initiated in recent years and no conclusive results are yet available.

Table 59: Studies on combining fodder production with other production systems

	Location	References[1]
Crop rotation, cropping sequences		
Crop rotation studies	Bumthang, Yusipang, Phubjikha	1, 2, 3, 4, 5
Cropping sequence studies	Phubjikha	1, 2, 5
Cropping after white clover	Bumthang	6
Systems with fruit trees		
White clover in apple orchards	Bumthang	4
Legume species in apple orchards	Bumthang	6
Effects of sub-tropical legumes in orchards	Zhemgang	6
Systems with timber trees		
Silvopastoral studies	Bumthang	6, 7
Other systems		
Soil conservation	Zhemgang	6

[1] References: 1 – ARC 1989; 2 – ARC 1990; 3 – Gyamtsho 1986; 4 – Roder 1983c; 5 – Roder et al. 1993b; 6 – RNR-RC Jakar 1997a; 7 – Rinchen and Roset 1997

Crop rotation and cropping sequence studies

Increased soil fertility and yields in field crop and horticulture systems have been postulated to be one of the major advantages of fodder development (AHD undated; Roder 1982c; 1990c). Although several attempts have been made to investigate such effects in a variety of cropping systems, little quantitative data has been generated to support this hypothesis.

A long-term crop rotation study carried out in Bumthang combining white or red clover based fodder with buckwheat, potato, and wheat did not provide conclusive results (Dorjee 1989; Gyamtsho 1986). A crop rotation study using white clover for one to three years was carried out in Bumthang and Yusipang; but no consistent effects on potato yield were demonstrated (ARC 1992).

Crop rotation studies carried out in Phubjikha showed that potato tuber yields were increased by 34% (above continuous potato production) if the previous crop was lupine *(L. mutabilis)* and by 40% if it was white clover (Table 60) (Roder et al. 1993b). Similarly, compared to continuous potato cultivation the number of volunteer potatoes, a troublesome weed, was reduced by 73% if the previous crop was white clover (Roder et al. 1993b).

Table 60: Effect of lupine and white clover on potato yield and volunteer plants

Rotation	Yield[1] (kg m^{-2})	Volunteer potato[1] (plants m^{-2})
Continuous potato	2.1^{B}	0.56^{A}
Rye-lupine-potato	2.8^{AB}	0.31^{B}
Clover-clover-potato	2.9^{A}	0.15^{B}

[1] Numbers followed by the same letter are not significantly different at the 0.1 probability level

Source: Roder et al. 1993b

Systems with fruit trees

The effect of white clover grown under apple trees was evaluated at Nasphyel farm (Bumthang). White clover was found to have a strongly positive effect on the N-status of apple trees one year after initiation of the study (Roder 1983c). Various studies are under progress to evaluate the effect of fodder peanut *(Arachis pintoi)* in subtropical plantation systems with citrus or areca nut (Figure 49).

Systems with timber trees

With the forthcoming introduction of the private and social forestry rules under Bhutan's Nature Conservation Act, 1994 (MOA 1997b), silvopastoral systems are likely to offer excellent opportunities for landowners in temperate areas. Several studies have been initiated to evaluate the interaction of pasture plants and blue pine or larch trees under livestock grazing (Rinchen and Roset 1997; RNR-RC Jakar 1997a) (Figure 50).

In a study initiated in 1991, legume species and P-treatment were found to have no effect on tree performance (Rinchen and Roset 1997), but six years after its establishment, this silvopastoral system with white clover based pasture made a very good impression and seems to offer a viable and interesting alternative to either pangshing cultivation or exclusive timber production systems. Early returns from livestock products will make it easier for resource poor farmers to make the long-term investments in timber production.

Figure 49: Fodder peanut *(Arachis pintoi)* as a cover crop under areca nut

Figure 50: Agroforestry study evaluating herbage and timber production with larch and white clover grass combination

Chapter Four
Extension

Extension recommendations

Many documents have provided recommendations for extension activities in Bhutan. Many of these recommendations have been repeated again and again, yet many have never been implemented on a large scale. The recommendations based on research activities have been discussed in Chapter 3. The most important documents providing extension recommendations are listed in Table 61.

Table 61: Major extension recommendations for fodder

Recommendations	Year	Reference
A package of practices for temperate regions including recommended species, and establishment and fodder conservation techniques	1978	AHD undated
Recommended fodder species and methods for temperate and subtropical regions	1981	Roder 1981a
Lecture notes on recommended species, establishment methods, grassland management, and arable fodders	1982	Roder 1982c
Economic winter feed production through standing hay	1978 1983	Logan 1978 Roder 1983d
Recommended fodder tree species	1982 1987	Roder 1982b; AHD 1987a
Package of practices for selected fodder tree species	1980s	AHD undated
Urea treatment of straw	1987	AHD 1987b
Fodder species for subtropical areas	1987	AHD 1987a
Fertiliser recommendations for subtropical regions	1990	Gibson et al. 1990

Extension network

Modest extension activities aimed at increasing fodder production or fodder quality started in the late 1960s and early 1970s. These early activities were sporadic and generally related to projects that were limited in time and space. Most of the development centres initiated in the late 1960s such as Samtse, Lingmethang, Gogona, and Bondey government farms at some stage promoted fodder species (Maurer 1985; Roder 1988b; Roder et al. 1997b; Wangdi

1979). Although these activities may have had little direct impact they provided important experience for later programmes.

The Bhutanese Government's Animal Husbandry Department began to build up a network of extension centres in the 1970s. These centres were placed at geog level and were generally staffed by technicians with basic veterinary training to provide health care and to supervise crossbreeding activities. Extension workers for fodder development, also known as pasture assistants, were trained from 1978 onwards and placed in these extension centres. Some of these fodder specialists were placed at the geog level whilst others were attached to the dzongkhag headquarters.

The responsibility for all livestock-related extension activities was entrusted to extension workers at the geog level after the reorganisation of the training programme, which followed the inception of the Natural Resource Training Institute and the reorganisation of the Ministry of Agriculture in 1995. Their responsibilities covered health, general livestock management, and fodder resource development aspects. The training of extension workers and field activities remains strongly biased towards animal health.

As mentioned above, fodder development, especially extension, was also an important component of the two large livestock development projects, the HLDP (1986-1993) and the HAADP (1987-92), as well as of the earlier Rural Development Project Bumthang (1974 to 1985).

Extension programmes

Herbaceous species in temperate regions

The earliest documented and sustained extension activities focusing on fodder development started in Bumthang dzongkhag in 1978 (Roder 1980; 1983b). Seed was sold at a nominal rate of Nu 2.0 per kg (approximately 10% of the production cost) and phosphate fertiliser was provided free of cost. The following practices were recommended.

- Species and seed rate (kg ha^{-1}): white clover 4 kg, Italian ryegrass 8 kg, cocksfoot 4 kg, and tall fescue 4 kg
- Inoculation: clover seed was inoculated and coated with gum arabic and rock phosphate prior to distribution or broadcasting.
- Establishment: the preferred method of establishment recommended was under-sowing into sweet buckwheat. Transplanting of white clover without cultivation was also recommended.
- Management: both grazing and cut and carry systems were recommended; scythes were introduced and distributed at subsidised rates.
- Preservation: winter feed preservation through hay or silage making was recommended; simple pit silo systems were introduced.

This package of practices became the model for the nationwide extension programmes promoted by the Department of Animal Husbandry (AHD) in the Fifth, Sixth, Seventh, and Eighth five-year plans, with the first countrywide activities initiated in 1978 (RGOB 1997). This recommended package has changed little over the years, with only three main adaptations:

- when more cocksfoot and tall fescue seed became available it became possible to replace some of the Italian ryegrass seed with these species;
- seeds were distributed free of charge from 1983 onwards; and
- fertiliser subsidies were discontinued in 1996.

Early activities in Bumthang dzongkhag profited from the following special circumstances not present in other dzongkhags (Roder 1980; 1983b).

- The promotion of fodder species coincided with a rapid rise in potato cultivation and the introduction of bullock-drawn implements for potato planting, weeding, and earthing-up. In the initial phases of the programme it was farmers who grew potatoes who were most interested in producing fodder and making silage because of the need to feed the draught animals during the latter part of the dry winter season.
- The Rural Development Project, Bumthang, which spearheaded the promotion programme, was responsible for both agriculture and animal husbandry development programmes in the dzongkhag.
- Intensive fodder development activities carried out in two government farms located in Bumthang dzongkhag (the Rural Development Project and the Sheep and Yak project, Dechenplerithang) served as inspiring examples.

In spite of these favourable circumstances, progress in the initial years was slow (Figure 51). An early assessment of nationwide activities highlighted the following problems (Roder 1981a):

- extreme variations in climate and other environmental conditions;
- unfavourable rules and regulations regarding grazing lands;
- low motivation of farmers as cultivating fodder was a new concept and there were no examples;
- high phosphate inputs were required;
- expensive inputs (seeds) were given to the farmers free or at a nominal cost, thus farmers were not motivated to optimise coverage and establishment success; and
- inoculation failures due to poor quality inoculum.

The progress of fodder development activities in Bumthang dzongkhag was reviewed in 1986 (Helvetas 1986). From 1981 to 1985 an average of 0.25 ha was sown to white clover and grass by participating farmers in the dzongkhag. At the end of this four-year period only 61%

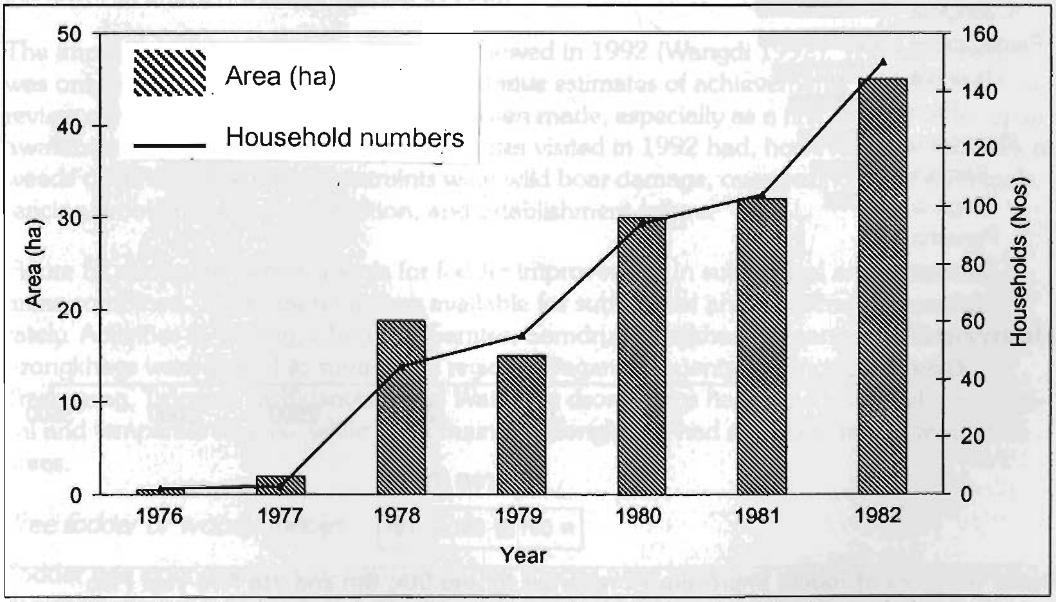

Figure 51: Fodder development in Bumthang dzongkhag during the 4th plan period

of the sown area was still present as improved grassland. Most of the failures occurred in the first 12 months after seed broadcasting due to (Helvetas 1986)

- over-grazing;
- lack of interest due to free inputs and the target-driven programme;
- failure to follow fertiliser recommendations; and
- insufficient support and follow up provided by project staff and government extension staff.

Despite the slow pace of improvement in Bumthang dzongkhag, the results were still far superior to those in other areas. By the end of the 7th Five Year Plan period (1997), fodder improvement activities were reported to have been carried out over an area of more than 2,800 ha (Figure 52). No other dzongkhag has achieved comparable results to Bumthang. This lead is even more impressive when it is considered that Bumthang ranks only eighteenth for the number of rural households and eighth for the number of cattle and yak. The other regions that have achieved the best results are those with similar conditions to Bumthang, especially areas in Wangdue and Trongsa dzongkhags.

Gyamtsho (1992) reviewed the progress of HAADP. He focused largely on the implementation of a land allotment scheme. No quantitative data were provided on the achievements of the fodder development programme, and the author felt that HAADP's activities had only had a minor effect on livestock nutrition.

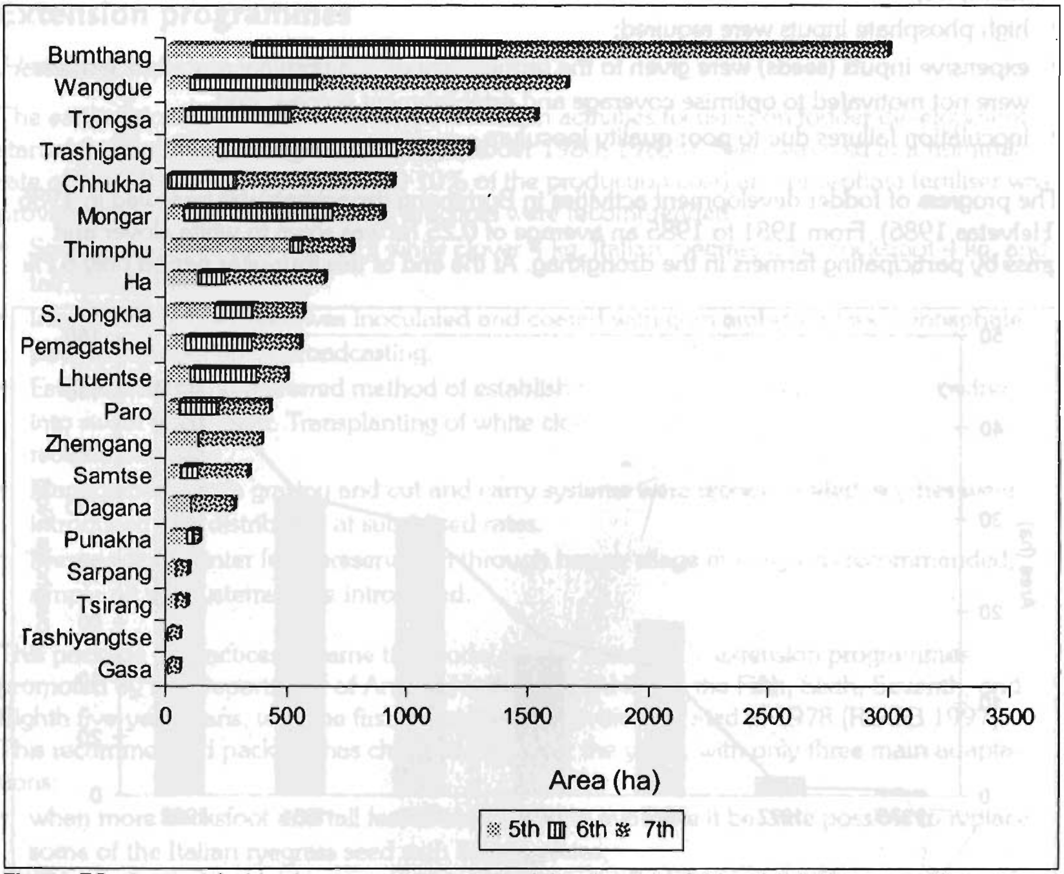

Figure 52: Area of fodder improvement reported for the 5th, 6th and 7th Five-year Plan periods

Herbaceous species in subtropical regions

Due to a lack of seed and suitable methodologies, the extension activities in subtropical regions have been less successful. The recommended species have changed with every plan period (Table 62).

Table 62: Species recommended for subtropical areas during the 5th to 7th Five Year Plan Periods

Plan period	Species recommended	
Fifth Plan[1] (1982-87)	Kikuyu grass	Pennisetum clandestinum
	Guinea grass	Panicum maximum
	Setaria	Setaria sphacelata
	Rhodes grass	Chloris gayana
	Napier grass	Pennisetum purpureum
	Silverleaf desmodium	Desmodium uncinatum
	Glycine	Neonotonia wightii
	Stylo	Stylosanthes guianensis
Sixth plan[2] (1987-92)	Signal grass	Brachiaria decumbens
	Molasses grass	Melinis minutiflora
	Guinea grass	Panicum maximum
	Setaria	Setaria sphacelata
	Centro	Centrosema pubescens
	Silverleaf desmodium	Desmodium uncinatum
	Greenleaf desmodium	Desmodium intortum
	Siratro	Macroptilium atropurpureum
	Glycine	Neonotonia wightii
	Stylo	Stylosanthes guianensis
Seventh plan (1992-97)	Ruzi grass	Brachiaria ruziziensis
	Molasses	Melinis minutiflora
	Greenleaf desmodium	Desmodium intortum

[1]Roder 1982c; [2]AHD 1987a

Fodder extension activities in Chhukha and Samtse dzongkhags are referred to in Hall (1988a; 1989), in Mongar dzongkhag in Rumball (1988a; 1989), and in Pemagatshel dzongkhag in Gibson (1988b; 1989b) and Roder (1988a). Some of the issues discussed in these papers are: the appropriateness of extension recommendations and targets (Gibson 1988b), the results of extension activities (Hall 1988a; Rumball 1988a), input supply problems (Gibson 1989b), and management problems in improved pastures (Hall 1988a).

The impact of the HLDP activities were reviewed in 1992 (Wangdi 1992). The assessment was only qualitative and lacked any quantitative estimates of achievements and impact. The review concluded that good progress had been made, especially as a first step, in creating an awareness for fodder development. Many sites visited in 1992 had, however, reverted back to weeds or shrubs. The main constraints were wild boar damage, overgrazing by wild animals, fencing problems, weed competition, and establishment failure.

Figure 52 shows the achievements for fodder improvement in subtropical and temperate areas combined. There are no figures available for subtropical and temperate areas separately. Activities in Tsirang, Chhukha, Samtse, Samdrup Jongkhar, Sarpang, and Pemagatshel dzongkhags were limited to subtropical regions. Dagana, Lhuentse, Mongar, Zhemgang, Trashigang, Trongsa, Tashiyangtse, and Wangdue dzongkhags had activities in both subtropical and temperate regions, while the remaining dzongkhags had activities only in temperate areas.

Tree fodder or woody species

Fodder tree extension activities with local tree species were launched in 1982 (Roder 1982b). Farmers were advised to plant *Artocarpus lakoocha, Bauhinia variegata, Bauhinia purpurea,* *Litsea polyantha, Ficus roxburghii, Ficus nemoralis, Brassaiopsis hainla, Saurauia nepaulensis, Prunus cerasoides,* and *Salix babylonica* ((Roder 1982b). During the Fifth Plan period the farmers were paid Nu 0.5 for each fodder tree they planted.

The only exotic fodder tree species recommended and distributed to farmers were *Leucaena leucocephala* and black locust (*Robinia pseudoacacia*) (Roder 1982b; 1984; 1989). Farmers were, however, reluctant to accept these exotic species (Roder 1984). Psyllid infestation of *Leucaena leucocephala* was observed at various locations (Gibson 1989b). Fewer species were recommended in the Sixth Plan (AHD 1987a), they were limited to *Artocarpus lakoocha, Bauhinia variegata, Bauhinia purpurea, Ficus roxburghii, Ficus cunia, Ficus lakoor, and Celtis australis*. The farmers' interest in tree fodders was highest in those regions where tree fodders were traditionally used such as Samdrup Jongkhar, Trashigang, Mongar, and Samtse dzongkhags (Figure 53). The achievements from the tree fodder extension activities were reviewed in a survey carried out in a number of dzongkhags in 1996 (Tshering et al. 1997a).

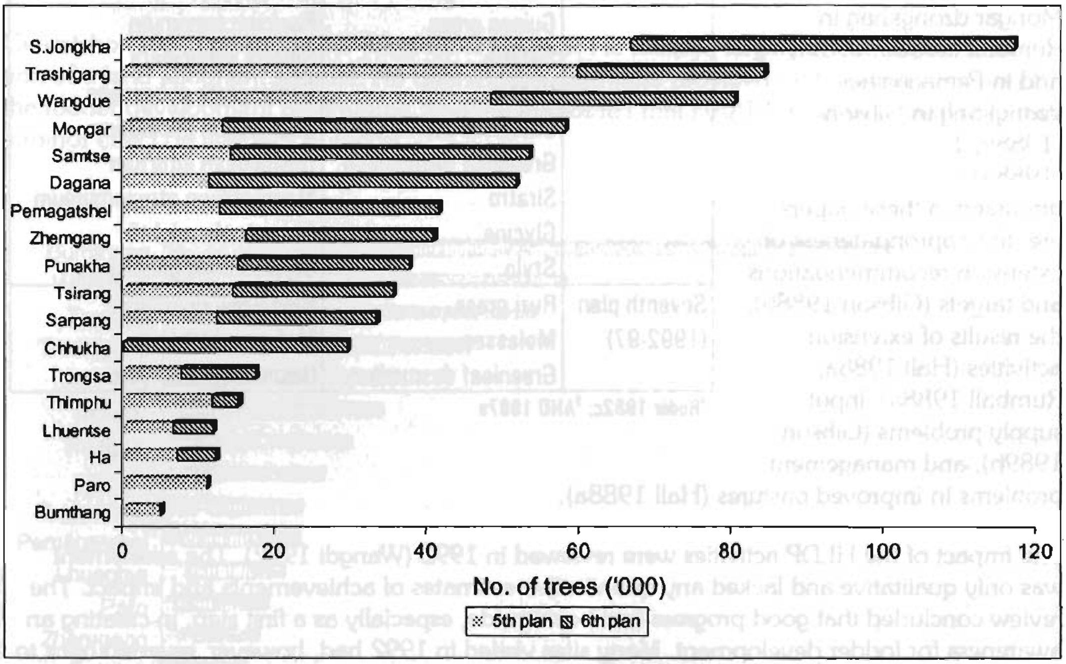

Figure 53: Number of fodder trees planted during 5th and 6th Five-year Plan period

In the survey of 1996, most of the farmers' fodder trees were found to originate from saplings collected from the forest or from trees raised by the farmers themselves (Table 63). Only in Wangdue dzongkhag did the majority come from official sources.

Paddy straw treatment and urea molasses blocks

Urea treatment of paddy straw was an important component of the extension programme during the Sixth and part of the Seventh Plan. Farmers were trained in the methods of treatment and provided with free urea. An extension booklet was issued in 1987 (AHD 1987b). The advantages of urea treatment were said to include

- higher palatability and intake by livestock;
- better digestibility;

- higher N intake (from the urea); and
- fewer liver fluke infestations in livestock.

The response of farmers to this method of paddy treatment was documented for Paro in 1986 (van Wageningen 1985; 1986). In 1996 a survey was carried out to evaluate the experience of past extension activities with paddy straw treatment (RNR-RC Jakar 1997a). Information was collected at the household level in six dzongkhags using a formal questionnaire. The two geogs with the most intensive activities in straw treatment in each dzongkhag were selected, and all households in 20-50% of the villages in these geogs included in the survey. The results are summarised in Table 64.

Table 63: Source of planting material

Dzongkhag	Source of planting material (% of households)[1]		
	Wild[2]	AHD[3]	Self-seeded
Punakha	39	38	27
Wangdue	37	69	24
Trongsa	100	0	0
Chhukha	89	24	27
Zhemgang	91	1	9
Lhuentse	95	10	0
Mongar	83	17	0

[1]The total is greater than 100 because some households had saplings from two sources (AHD and wild); [2]mostly collected from the forest; [3]Animal Husbandry Department
Source: Tshering et al. 1997b

The major findings were that
- liver fluke was considered a problem by the majority of households;
- almost all households fed paddy straw to their livestock during the dry season;
- many of the respondents had tried the urea treatment method but all of them had discontinued its use;
- a large percentage of households reported reduced intake by livestock fed with treated straw; and
- the increased labour requirements and the cost of the urea were felt to be disadvantages.

Following the poor response to the paddy straw treatment programme, the use of urea molasses block was recommended. Bajracharya (1992) provides some discussion of these activities. The method was tested on cattle, yak, and sheep at village level in five dzongkhags with 91 contact farmers. Increased milk production was reported in some cases but, although promising, this programme was not continued.

Table 64: Summary of paddy straw treatment survey findings in two selected geogs of each dzongkhag

Dzongkhag	Sample (no.)	Cattle (no./HH)	Liver fluke problems (%)	Feeding straw (%)	Tried treated straw (%)	Straw intake reduced when straw treated (%)
Punakha	86	6.7	35	88	23	15
Wangdue	120	12.6	60	89	76	61
Trongsa	29	9	52	100	72	40
Thimphu	76	6.3	78	95	46	32
Paro	102	2.3	93	100	51	17
Chhukha	109	7.2	34	89	32	23

Source: Roder 1998b

Impact of extension activities

It is difficult to assess the overall impact of the fodder development extension activities, although some of the survey data can be used to quantify or to estimate changes that have occurred (Table 65). Clearly other factors will have been involved in addition to direct extension like peer group example and information, changing needs, and introduction of improved livestock, but to some extent at least the changes are likely to be the direct result of the government's fodder development activities. Effects were noticed not only on the area of improved pasture and the quantity and quality of available fodder, but also on

- the seasonal availability of fodder (winter fodder);
- animal production;
- cattle migration ;
- the productivity of field and horticultural crops and labour requirements for their production; and
- soil conservation.

Table 65: Changes in fodder and livestock production in Bhutan partially due to RGOB's fodder development activities[1]

Component of the system	At national level (%)	Selected pockets in temperate regions (%)
Dry matter production increase	1-2	10
Fodder quality increase during summer	5	50
Fodder quality increase during winter	20	200
Milk production increase	100	500
Cattle migration (reduction)	15	60

[1] Estimates by the author

Achievements reported and area covered

All fodder development activities have been strongly target oriented and only limited attempts have been made to assess their impact. The only quantitative data available are from detailed follow-up activities carried out in Bumthang dzongkhag during the 1980s (Helvetas 1986) and from a later survey carried out in selected dzongkhags (Roder 1998b).

Herbaceous fodder and pasture development

During the initial years the reported results of fodder development activities were relatively good in Bumthang where a 61% success rate was reported for the Fifth Plan period. In other dzongkhags, especially in eastern Bhutan, the impact was much less. One observer reported that fodder development activities in the east of Bhutan only started with the Sixth Plan (Wangdi 1992). This is in strong contrast to the officially reported achievement of 600 ha of pasture improvement reported for the Fifth Plan.

According to the achievements reported during the 5th, 6th, and 7th Plan periods (1981-1997), the area established under improved pasture by individual households was relatively high, especially for Bumthang, Trongsa, and Wangdue dzongkhags (Figure 52). However, the coverage reported in the 1997 survey (Roder 1998b) was substantially below the levels previously reported (Tables 66 and 67). In this survey, Bumthang dzongkhag – thought of as the most advanced in fodder resource development – showed only 10% of the reported area remaining under improved fodder. This disappointingly low proportion of improved pasture remaining is probably due to the following:

- a high proportion of the large areas covered during the 5th and 6th Plan periods (Figure 52, Table 66) have reverted back to other land uses (Roder 1998b);
- earlier fodder development activities were driven by demand for subsidised fertiliser rather than the desire to improve fodder; and
- over-reporting of achievements.

In the 1997 survey, Sephu and Phubjikha (both Wangdue dzongkhag), Chumey (Bumthang dzongkhag), Tangsibi (Trongsa dzongkhag), and Trong (Zhemgang dzongkhag) geogs had the highest area of improved pasture per household (Table 67). These geogs also had more than half an acre (0.2 ha) improved pasture available per milking cow.

Fodder tree development

In 1997, the number of fodder trees present per household and their source was compared with the number distributed per household in the course of extension activities from 1982 to

Table 66: 1997 survey results of existing acreage of improved pasture compared to values reported in RGOB official reports

Dzongkhag	Reported achievement 1982-97 (ha)		Existing improved pasture observed in 1997 as % of reported[1]
	Total	Area per HH	
Paro	411	0.16	36
Wangdue	1,645	0.57	39
Trongsa	1,519	0.85	45
Zhemgang	378	0.16	70
Bumthang	2,980	1.98	10

[1] In the blocks surveyed
Source: Roder 1998b

Table 67: Area of improved pasture per household in various geogs

Dzongkhag	Geog	Households with improved pasture (% of total HH)	Pasture area per household with improved pasture (ha/HH with pasture)	Pasture area for all households (ha/total HH)	Area per milking cow (ha)
Paro	Dopjari	67	0.24	0.17	0.08
	Narja	54	0.16	0.08	0.04
Wangdue	Phubjikha	88	0.65	0.56	0.25
	Sephu	93	0.73	0.67	0.35
Trongsa	Tangsibi	75	0.69	0.51	0.22
	Drakten	35	0.28	0.11	0.08
Zhemgang	Nangkhor	40	0.20	0.07	0.04
	Trong	48	0.81	0.39	0.25
Bumthang	Tang	72	0.40	0.30	0.17
	Chumey	74	0.81	0.59	0.26

Source: Roder 1998b

1996 (Table 68). The survival of fodder trees distributed under the extension programme was estimated to be less than 20% in all dzongkhags except Chhukha. Since the survival rate calculation was based on the average rather than the actual number of trees distributed per household, the actual survival rates may well be lower. The high survival rate reported for Chhukha may be due to the relative low proportion of fodder trees originating from government sources. Chhukha reported the highest tree numbers per household, while the numbers distributed were low.

Dry matter production

Between 1982 and 1997 the following achievements were reported:

- 13,760 ha of pasture established;
- 735,819 fodder trees planted; and
- extensive uptake - more than 50% of rice-growing households in some dzongkhags - of paddy straw treatment.

Table 68: Impact of extension activities on fodder trees available and tree survival

Dzongkhag	No. of trees per HH			Survival
	Distributed	Trees present in 1997		
	from 1982-96	Total	From AHD	(%)
Punakha	18	5.3	1.9	11
Wangdue	29	6	3.2	11
Trongsa	12	12	<0.5	<5
Chhukha	9	53	9.0	100
Zhemgang	22	17	<0.5	<5
Lhuentse	5	8.1	0.8	16
Mongar	12	11.8	2	17

Source: Roder 1998b

However, at the national level the impact of fodder development activities on the total dry matter production has been limited. Assuming a success rate of 10% for trees planted and 20% for the pasture improvement activities, and an additional dry matter yield of 1.5t per acre for improved pasture and 30 kg per tree, then 10,200t additional dry matter has been produced as a result of pasture development activities and 2,200t from trees. With an intake of 8 kg per day this amount is equal to the annual feed requirements of 4,250 animals or about 1-2% of the total population of large ruminants.

Although the impact at the national level seems small, a strong impact on the dry matter production is visible in areas that have benefited from a high concentration of fodder development activities such as Sephu and Phubjikha in Wangdue dzongkhag, Tangsibi in Trongsa dzongkhag, and Tang and Chumey in Bumthang dzongkhag (Table 67). Households in these geogs have between 0.16 and 0.35 ha of improved pasture per milking cow (Table 67) and a large proportion of them consider improved pasture as an important fodder resource during the summer season (Table 69).

Seasonal fodder availability - winter fodder

Tree fodder species are almost exclusively used for winter fodder. Herbaceous fodder species contribute substantially towards improved winter fodder quality and quantity. Hay is especially important at higher elevations and between 40 and 78% of respondents in Tang, Chumey, Phubjikha, and Sephu considered hay, mostly made from improved pasture, as one of their main winter fodder resources (Figures 54, 55, Table 69).

The traditional winter fodders such as hay from native grasses, paddy straw, buckwheat straw, the grazing of native pasture, and tree fodder leaves are all poor quality livestock feeds. Most of them are insufficient to even maintain the body weight of large ruminants. Therefore, even small improvements in the quality of winter fodder will have substantial impacts on infertility problems, mortality, and production over the entire season.

Nutritional quality and animal production

The impact of tree fodder and of subtropical herbaceous fodder species on the nutritional quality of the diet of Bhutan's livestock has probably been negligible. In temperate regions, however, the introduction of white clover has resulted in a substantial increase in the fodder quality in both the wet and dry seasons.

White clover has spread over large areas of permanent grazing land. Because of its excellent nutritional qualities (high palatability, high protein content, and low crude fibre), small additions of white clover to the native grassland vegetation substantially increase the fodder quality. It is largely through this improvement that the milk potential of crossbred animals can be realised (Table 70) and this has been the main impact of fodder development on animal production.

Table 69: Importance of improved grassland for grazing and making hay

Dzongkhag	Geog	Important fodder source (%)[1]		
		Improved pasture		Hay
		Summer	Winter	Winter
Paro	Dopjari	49	0	67
	Narja	12	1	0
Wangdue	Sephu	23	4	60
	Phubjikha	61	5	67
Trongsa	Tangsibi	72	26	18
	Drakten	15	15	0
Zhemgang	Trong	20	10	0
	Nangkhor	5	0	0
Bumthang	Tang	7	49	48
	Chumey	30	30	78

[1] Percentage of households ranking improved pasture or hay as the most (first rank) or second-most important fodder resource
Source: Roder 1998b

Figure 54: White clover grass cut with sickle in cut and carry system

There is no reliable data on increases in milk production. It is, however, estimated that the milk production potential of white clover based grassland and hay is between two and five times more than that of grassland or hay without white clover. The combined effect of increased yield and improved quality could therefore have resulted in between four and ten-fold increases in milk production (Figure 56).

Figure 55: Cutting white clover/grass with scythe, for hay making

Table 70: Milk production potential of selected fodder sources

Fodder type	Potential milk production (kg/animal)
Local pasture with white clover	15.0
Hay from white clover/grass mixtures	14.0
Local pasture: summer	8.0
Hay from local pasture	2.0
Local pasture: winter	<0.5

Source: authors of review, estimates based on fodder analysis data shown in Table 36

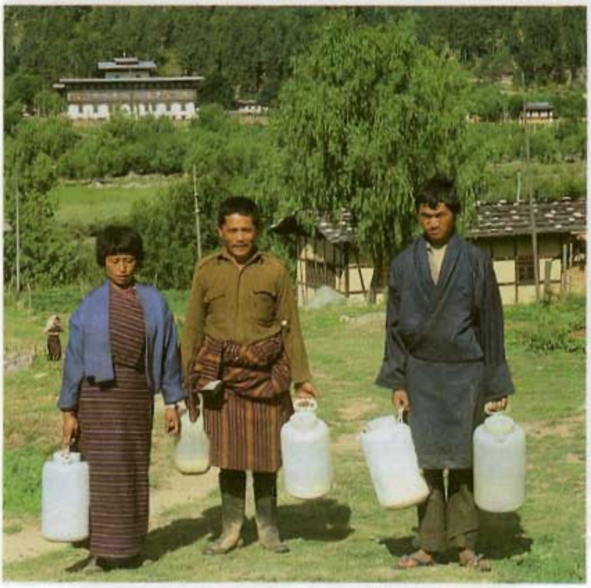

Figure 56: Farmers delivering milk to the milk processing plant in Bumthang

The primary reason cited by local farmers for additional fodder resource development was the expected increase in milk production. Several of the other reasons cited "plans to bring in cross-bred animals", "fodder needed for improved cattle", and "increases in cattle numbers" are also related to milk production (Figure 57). The high emphasis on milk production is also evident from the response to the question "what animals are the primary users of improved fodder" (Roder 1998b, Figure 58).

Improved forage production over the years has to some degree contributed to improvements in the livestock sector. Although no quantitative data are available, it is unquestionable that the increased availability of livestock products have made an important contribution to human nutrition in Bhutan. In addition, the sale of milk products is an important source of cash for many households (Table 71).

The number of yak and cattle doubled from around 165,000 in 1976 to 335,000 in 1995 (LUPP 1995), and it can be assumed that this also led to a 100% increase in feed requirements. The increased requirement has largely been met from traditional fodder resources but the combined effects of increased dry matter production, better seasonal availability of forage, and improved nutritional qualities of the forage have contributed substantially to making this tremendous increase in livestock numbers possible.

Impact on traditional cattle migration

The traditional system of bringing cattle down to lower elevations during the cold, dry winter has many disadvantages, in particular that it spreads livestock diseases, limits the production potential of livestock, and limits the options for field crops and horticultural

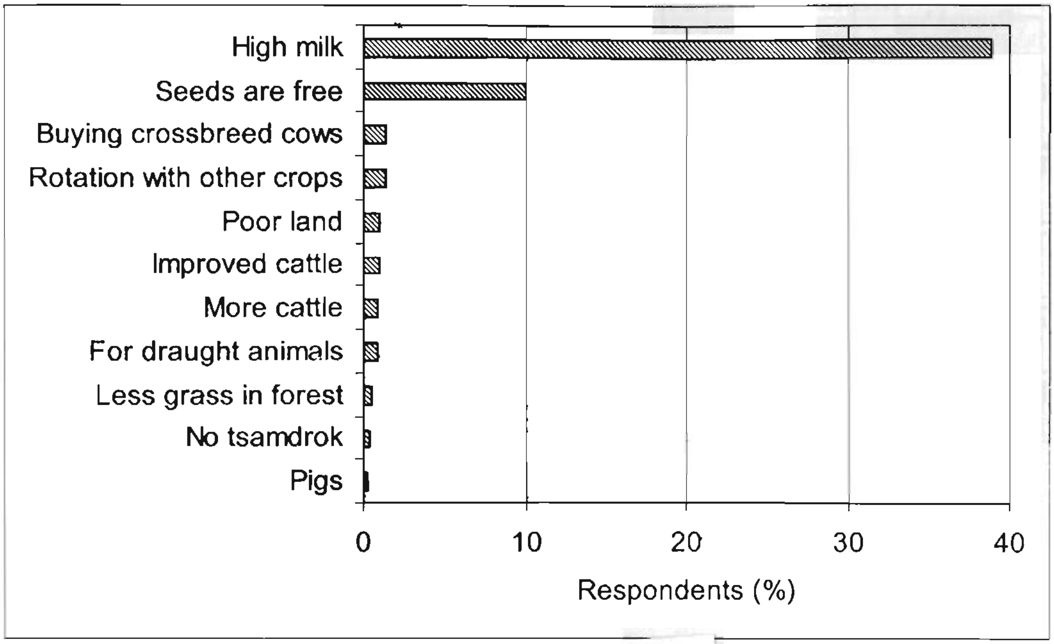

Figure 57: Reasons cited for planting more improved fodder

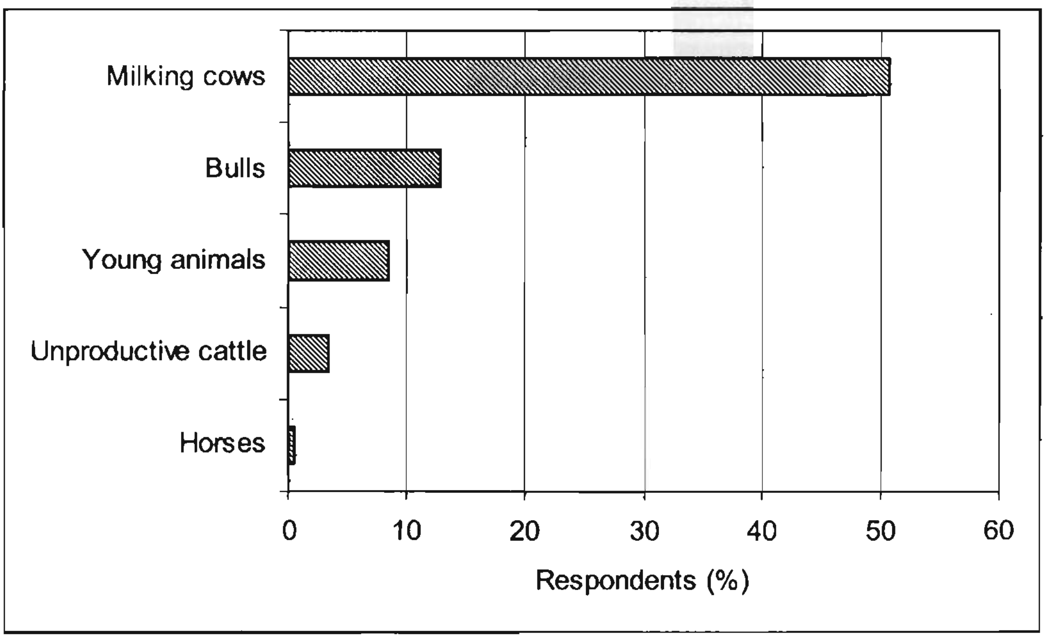

Figure 58: Use of improved fodder

Table 71: Households selling milk products and estimated income				
		Households		
Dzongkhag	Geog	Selling milk products (%)	Income from milk products (Nu/year)[1]	HHs earning > Nu 10,000 per year (%)[1]
Paro	Dopjari	63	6,054	46
	Narja	41	4,165	31
Wangdue	Sephu	75	5,084	26
	Phubjikha	51	2,787	7
Trongsa	Tangsibi	80	4,875	18
	Drakten	32	1,575	5
Zhemgang	Trong	42	2,311	8
	Nangkhor	21	1,096	3
Bumthang	Tang	33	810	3
	Chumey	21	737	1

[1]Average of all households; 40 Nu approx. US$ 1; 10,000 Nu approx US$ 250

production in lower areas. Changes in these migration patterns are, however, only possible if alternative sources of feed can be found for the critical periods. The fodder development activities in the temperate regions have contributed substantially towards reducing cattle migration.

Bourgeois-Luethi (1998) has reviewed the impact of crossbreeding activities on cattle migration. Various references discuss the extent of migration but quantitative information on changes in migration is scant. A survey carried out in 1983 reported a 19% reduction in migration (Muller-Jaag 1984).

Impact on soil conservation

A large proportion of the improved pasture established in Bumthang, Mongar, Wangdue, and Ha dzongkhags was seeded into buckwheat crops in pangshing production systems. In the traditional pangshing systems, the plant cover after the buckwheat harvest remains very poor for up to five years. Establishing white clover based fodder mixtures combined with the application of P fertiliser has greatly improved plant cover and soil conservation. Furthermore, several of the legume and grass species introduced have been recommended for soil conservation.

Gender impacts

Farming activities are generally carried out jointly with all family members contributing. Some crop production activities do have strong gender divisions, however (Table 72, Figure 59) (RNR-RC Jakar 1998b). Ploughing is a job carried out largely by men whilst women do most of the manure carrying and rice weeding. Gender differences were less marked in Zhemgang and Trongsa than in Paro and Wangdue (Table 73). Except for Zhemgang, this study found that livestock-related jobs are more likely to be carried out by women, especially milking and milk processing. The gender differences are less pronounced for new activities associated with fodder resource development such as cutting and carrying grass. The higher proportion of women in most activities is partly the result of a gender imbalance in the available work force. Men are more likely to leave the farms looking for temporary or long-term off-farm employment.

Lipper (1989) found that in Chhukha and Samtse dzongkhags, cheese and butter making was more likely to be carried out by women, while milking and fodder gathering were carried out by both men and women.

Table 72: Gender labour division for work related to livestock production					
	Ratio of female/male for a particular activity				
Type of activity	Paro	Wangdue	Trongsa	Zhemgang	Bumthang
Milking cows	4.4/1	13/1	1.9/1	1/1.2	3.9/1
Herding cattle	1/1	3.2/1	1.2/1	1/2	1.1/1
Cutting grass	2.3/1	6.3/1	1.9/1	1/1.8	1/1.4
Carrying grass	2.3/1	6.2/1	2/1	1/1.8	1/1.4
Feeding cattle	3.6/1	11/1	2.1/1	1.1/1	1.7/1
Decide on planting grass	1/1.7	1/1.7	1.2/1	1.1/1	1.4/1
Butter making	3.3/1	7.8/1	1.7/1	1/1.2	4/1
Cheese making	5.7/1	11/1	1.8/1	1/1.2	4/1
Selling butter/cheese	4/1	4.2/1	1.7/1	1.3/1	1.3/1
Carrying manure	13/1	19/1	4.2/1	1.3/1	1.2/1
Ploughing	1/25	1/20	1/10	1/25	1/20
Weeding rice	12/1	-	1/1.3	2.2/1	-
Weeding maize	12/1	-	1/1.8	1.7/1	2.4/1

Source: Unpublished survey data, RNR-RC Jakar

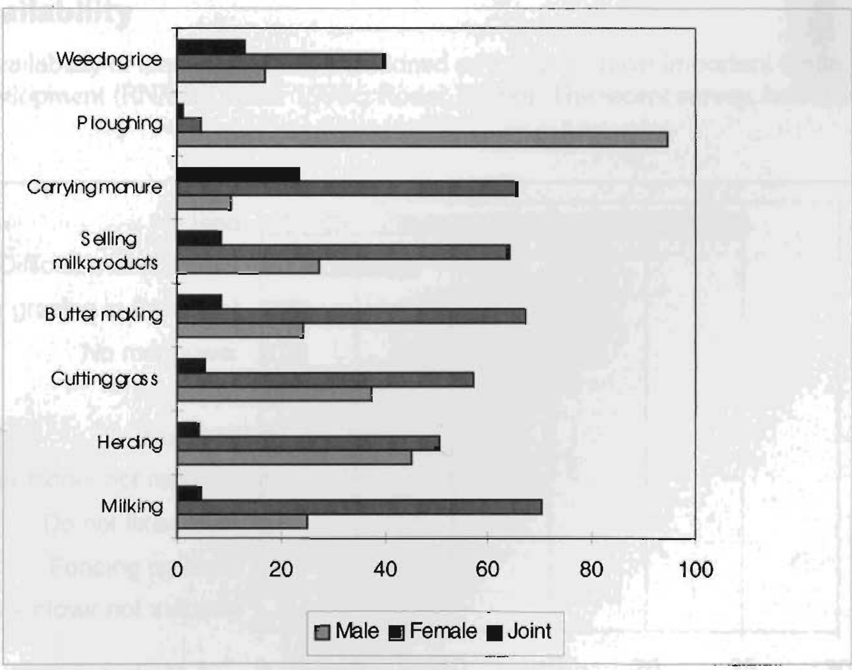

Figure 59: Gender-wise execution of selected activities

Table 73: Investigations into whether shortage of land is the real reason for lack of interest in fodder development

Dzongkhag	Geog	Land[1] (ha/HH)	% Respondents claiming land constraint	Milking cows/HH	HHs with milking cows	HHs selling cheese
Trongsa	Drakten	1.13	55	1.3	66	32
Bumthang	Tang	2.06	44	1.7	84	33
Trongsa	Tangsibi	1.46	38	2.3	86	70
Bumthang	Chumey	2.14	29	2.3	78	19
Paro	Dopshari	1.94	25	2.2	86	63
Paro	Narja	2.02	21	2.1	95	40
Zhemgang	Nangkhor	2.35	16	1.9	64	20
Wangdue	Sephu	0.57	13	1.9	77	74
Zhemgang	Trong	2.27	5	1.6	60	42
Wangdue	Phubjikha	1.01	5	2.2	89	50

[1] Kamshing, pangshing, and tsheri combined; HH = household

Source: Roder 1998b

Chapter Five

Constraints to Fodder Development

Land availability and damage by wild boar are the most frequently cited constraints to fodder development (RNR-RC Jakar 1996c). Similarly, Roder (1998b) reports that the question, "Why are you not planting more improved fodder" was most frequently answered with the argument that there is insufficient land available (Figure 60).

Although land limitation is frequently cited as the single most important constraint to fodder development activities, a closer analysis shows that the main constraints are more complex. The success of fodder and livestock development is impaired by the rules and legislation, the social customs and traditions, competition for other land use, a lack of available technologies, and inadequate processing and marketing facilities.

Land availability

The non-availability of land is generally mentioned as the single most important limitation to fodder development (RNR-RC Jakar 1996c; Roder 1998b). The recent survey, however,

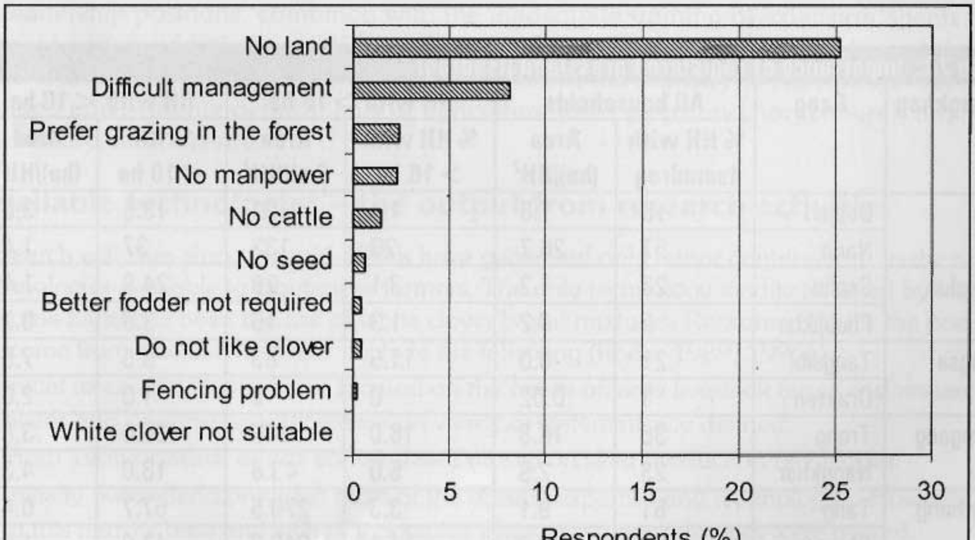

Figure 60: Why farmers are not planting more fodder

showed no relationship between the average size of landholding in a particular block and the response to the question whether land is limiting the extent of area used for fodder production (Table 73).

The response "not enough land" could also mean that, despite having a sufficient area, the land is too far from the house. Farmers generally like to have improved fodder growing near to their settlement. Most of the fodder areas developed on tsheri land in eastern Bhutan have reverted to weeds because of the difficulties in management caused by their distance from settlements.

Equally, "lack of land" should not be taken literally as the over-riding constraint for fodder development; it should rather be interpreted as fodder cultivation having less priority than field or horticultural crops. This lower priority results largely from animals not being productive enough to respond to better feed, and the technologies offered often being inappropriate. Government policies, subsidy structures and marketing support structures all favour rice production and the production of cash crops such as apple, potato, cardamom, and oranges. Farmers' reluctance to devote more land to growing fodder shows that they give more priority to field crops and horticulture (Table 73, last chapter). This priority may, however, change as smallholder farmers come to own more milking cows.

Rules and legislation

The resolution of uncertainties regarding the ownership of grazing lands has been pointed to as a prerequisite to improving Bhutan's grasslands (Gyamtsho 1996; RGOB 1997; Roder 1981a). However, discussions aimed at generating suitable rules and policies have continued over two decades without any tangible results (RGOB 1997).

In some areas the proportion of households with tsadrog is quite high (Table 74). Yet as a result of the uncertainties in rules and regulations the interest in improving these grasslands is generally low. Furthermore, the registered grassland areas are often far from homesteads and only migrating cattle herds can benefit from them. Less than 5% of the respondents who

Table 74: Importance of registered grassland (tsadrog)

Dzongkhag	Geog	All households		HH with > 10 ha		HH with < 10 ha	
		% HH with tsamdrog	Area (ha)/HH[2]	% HH with > 10 ha	Area (ha)/HH[3]	% HH < 10 ha	Area (ha)/HH[4]
Paro	Dopjari	15	1.8	1.4	100	13.6	3.0
	Narja	57	26.7	20	133	37	1.4
Wangdue	Sephu	28	1.2	3.1	28	24.9	1.4
	Phubjikha	5	0.2	1.3	15	3.8	0.7
Trongsa	Tangsibi	21	8.0	11.5	63	9.5	7.5
	Drakten	1	0.02	0	0	1.0	2.0
Zhemgang	Trong	36	16.8	16.0	100	20.0	3.8
	Nangkhor	23	2.9	5.0	43.8	18.0	4.3
Bumthang	Tang	61	9.1	3.3	270.5	57.7	0.4
	Chumey	53	38.2	11.1	340.3	41.9	1.0

[1] HH = household; [2] average of all households; [3] average for HH with > 10ha; [4] average for HH with < 10ha
Source: Unpublished survey data, RNR-RC Jakar 1998

expressed interest in additional fodder development are planning to use tsadrog lands for this (RNR-RC Jakar 1998).

Fodder grown on cropland and tree fodder planted by farmers on registered land of any class are new systems that are not covered under the existing Land Act.

Social customs and traditions

In Bhutan the socio-religious taboo that forbids the killing of any kind of animal makes it very difficult or even impossible for farmers in many areas to cull their unproductive animals. The large number of unproductive animals in most cattle herds substantially dilutes the positive effect of increased dry matter produced and improved fodder quality.

Other socio-economic factors that depress the possible impact of fodder development and livestock production include

- the concentration of large cattle herds with a limited number of better-off families, with many less well-off farmers having no milking animals;
- cattle migratory systems, which reduce the potential for cross-breeding programmes because crossbred animals are often unsuitable for walking long distances;
- the traditional, successful cross-breeding programme with mithun: this system, although resulting in immediate benefits, reduces the overall milk production potential of the cattle population and makes it difficult or impossible to make any advances by selective breeding (Burgeois-Luethi 1998).

Human resource development

The Ministry of Agriculture lacks personnel trained in fodder agronomy, the management of permanent grassland, and grassland ecology. Similarly, the curricula of the sole institution that trains extension personnel - the Natural Resources Training Institute (NRTI) - does not include appropriate instruction on fodder agronomy and the management of permanent grasslands. Fodder resource development is generally given secondary importance within the livestock extension activities due to the lack of professionals in leadership positions, combined with the inadequate training of extension agents. The present system of training in NRTI and implementation of extension activities at the district level simply follows the old system in which the Ministry of Agriculture was divided into separate departments of agriculture (field crops and horticulture), animal husbandry, and forestry.

Available technologies – the output from research activities

Research activities since the mid-1980s have generated only minor contributions to the set of technologies available to Bhutanese farmers. The only technology readily adopted by farmers in some areas has been the use of white clover based mixtures. Reasons cited for the poor outcome from research activities include the following (Roder 1989, 1996a).

- Initial research activities were focused on the needs of large livestock farms and research needs and opportunities for extension were not systematically defined.
- From 1986 onwards efforts concentrated mostly on seed production techniques.
- Initially Switzerland provided most of the outside expertise and technologies. However, due to this narrow base and lack of innovative ideas many opportunities were missed.
- A heavy dependence on expatriate advisors resulted in a lack of continuity.

- Meaningful inclusion of farmers in the research process was not given enough attention. No farmer participatory methods were used and insufficient on-farm work was carried out.
- Insufficient emphasis was also paid to institution building. Initial work was carried out in a project attached to the Ministry of Trade and Industry. A research centre established in 1982 (GAFRC) was changed to a seed multiplication centre after only four years.
- Some long-term crop rotation and agroforestry experiments had major design flaws and absorbed researchers' time over many years without giving any tangible results.

Processing and marketing

Except for a few pockets, milk producing farmers process the milk themselves using traditional systems. The processing of a few litres of milk into cheese and butter is very time consuming and reduces profitability (Figure 61).

Figure 61: Traditional butter making

Chapter Six

Future Directions

The Royal Government of Bhutan is strongly committed to improving the nutrition and increasing the incomes of the rural population, while at the same time maintaining or improving the country's biophysical resources (MOA/ISNAR 1992; MOA 1995; RNR-RC Jakar 1997f). Livestock production systems will have to fulfil the following major functions:

- provide livestock products for the rapidly increasing urban population;
- make a positive contribution towards maintaining the overall biophysical resources;
- provide equitable income opportunities for rural people; and
- complement field crops, horticultural, and forestry production systems by exploiting synergistic effects, optimising labour efficiency, and accelerating nutrient cycling.

It is hoped that in the near future livestock research and development will come to receive at least the same or even a higher share of the resources available to the Ministry of Agriculture. Several signs suggest that the importance given to livestock production is increasing. Such indicators and trends include

- the inherent limitations of Bhutan's topography and climate for sustainable field crop production are becoming more obvious and accepted by policymakers and planners;
- the expectations by the rural population for equitable income opportunities can no longer be satisfied by traditional cropping systems;
- except for horticultural production systems in selected pockets with favourable climates, dairy production offers the most profitable opportunities across a wide range of conditions;
- urbanisation is generating a fast growing demand for dairy products and meat; and
- the slaughtering of animals is becoming increasingly accepted in the urban areas.

Both research and extension must play an important role in the transformation of existing production systems. Key issues that need to be addressed to achieve the goals of equitable income levels and better nutrition without hampering the biophysical resources include policy issues, human resource development, and the identification and generation of new technologies.

Policy issues

Rules and regulations pertaining to permanent grazing lands (tsadrog)

The need for appropriate rules and regulations to govern the use and maintenance of natural grasslands is a major requirement for the optimal use of Bhutan's grassland resources

(Gyamtsho 1996; RGOB 1997; Roder 1981a). The suggestion in RGOB (1997) that a specific project be mandated to generate suitable rules and policies should be reconsidered. Rules and regulations need to address issues related to land ownership and taxation, the management and ownership of trees, and the management of other vegetation cover.

Rules and regulations on other fodder resources

Fodder grown on cropland and tree fodder planted by farmers on registered land of any class are new systems which are not accounted for in the Land Act. Additional rules and regulations are necessary to provide for the optimal development of these resources.

Self-sufficiency in food grains - food security

A high degree of self-sufficiency in food grains and improved food security remain important objectives of Bhutan's Ministry of Agriculture. It will, however, be important to maintain a realistic balance between efforts aimed at achieving food security and efforts aimed at providing equitable incomes for the rural population. When implementing subsidy systems and extension programmes that emphasise food security, caution is needed to avoid long-term negative impacts on the evolution of production systems adapted to local socio-economic and biophysical conditions.

Support for the processing and marketing of dairy production

Except for milk produced near urban centres, dairy products largely need local processing. The processing and marketing of livestock products should be given substantial support by the government.

Human resource development

It is of outmost importance, to recognise that:

- fodder agronomy, grassland ecology and the management of fodder resources involve a range of professions with very wide knowledge and skills;
- models of livestock production suitable for India, which emphasise using crop residues and concentrates as feed, are not suitable for most of Bhutan; and
- fodder agronomy and grassland ecology are more closely related to general agronomy than to animal health.

Persons trained in general agronomy have the necessary basic training for fodder agronomy. Similarly basic training in botany or agronomy provides a good base for a professional career in grassland ecology or grassland management.

Both the curricula of the NRTI and the framework for extension activities need to be revised to reflect the integrated and interdisciplinary nature of livestock and forage development in Bhutan's farming systems. At the same time, while integration is important, the need for specialist training and expertise should not be neglected.

The identification and generation of technologies

The limited resources available for research on Bhutan's very varied environment and farming systems demands rigorous priority setting. Future research programmes need to be flexible, realistic, simple and guided by the following assumptions.

- Basic research is only justified for issues unique to Bhutan.

- Technologies which are not location-specific can be directly tested by or introduced to producers.
- Livestock producers will remain the major clients, but increasingly there is a growing demand for research needed by other clients, espesially related to hydropower, conservation, and tourism.
- The present trend away from large migratory cattle herds to stationary smallholder systems with various degree of mixed farming is likely to continue.
- Synergistic and complementary effects of fodder production with field crop, horticultural, and timber systems will become more important.
- Permanent grasslands have limited potential for increased production, yet they will require continuing research in the areas of: ecological characterisation, biodiversity conservation, and management of national parks and water resources.
- Tree fodders will remain important in subsistence livestock systems, but have a limited contribution to make to the systems evolving for milk production from crossbreeds which have increased production potential.
- Socio-cultural taboos against slaughtering animals will continue to limit options for meat production systems - such as mutton - although the culling of unproductive cattle is gradually becoming more accepted.

These assumptions dictate that research activities should be largely limited to: monitoring trends in the resource base and the production technologies; identifying and importing pertinent information and technologies; and adapting technologies.

Extension

Fodder resource development will remain a major component of livestock extension activities. It will also become increasingly important in agroforestry systems, horticulture, and field crop systems. In drawing up future plans and programmes, flexibility and imagination need to be given more importance than experiences from earlier extension programmes.

The success of future extension activities will largely depend on the available human resources and the availability of appropriate technologies generated by the research programmes.

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Annex One

Quantitative Analysis of Grassland Vegetation in Bhutan

Tshuchida (1987, 1991) described grassland communities over a wide range of environments. He used Numata's Summed Dominance Ratio (SDR) to estimate the relative importance of a particular species (Numata, 1991). The observations made by Tsuchida were summarised by combining observations from similar elevations and are presented in the tables below.

Table A1: Plant communities at locations below 1000m, including those species unique to each site, along with SDR cover classes (adapted from Tsuchida 1987, 1991)

Species	Phunsholling 350m (3 sites)		Gaylephu 350m (3 sites)		Lingmethang 700-720m (5 sites)	
	SDR (%)[1]	Sites[2]	SDR (%)	Sites	SDR (%)	Sites
Chrysopogon aciculatus	47.3	2	18.3	1	20	1
Paspalum scrobiculatum			88.3	3	25	3
Desmodium heterocarpon	42.7	2	26.7	2	3.6	1
Eragrostis tenella	24.0	2	26.0	2	3.4	1
Cynodon dactylon			47.0	3	26	5
Ageratum conyzoides	14.0	2	23.7	3	4	1
Sida sp	43.3	3	23.3	2		
Tridax procumbens			21.7	2	32	3
Cassia occidentalis	5.7	1	10.0	1	14	2
Euphorbia hirta			2.0	1	40	4
Imperata cylindrica	19.3	1			20	1
Eleusine indica	23.3	2	11.7	1	0	
Fimbristylis sp	27.3	3	6.7	2	0	
Digitaria sp	25.0	1			2.6	1
Eragrostis unioloides	14.0	2	11.0	2		
Kyllinga sp	14.7	2			1.6	1
Phyllanthus virgatus	5.7	1	2.3	1	6.4	2
Arthraxon sp			2.7	1	3	1
Species unique to	**Phunsholling**		**Gaylephu**		**Lingmethang**	
>20 SDR (%)	*Paspalum orbiculare*		*Verbena* sp		*Heteropogon contortus* *Eupatorium adenophorum*	
11-20	*Mimosa* sp *Labiata* sp *Justicia adhatoda*				*Oxalis corniculata* *Artemisia indica* *Urena lobata* *Triumfetta rhomboidea*	
3-10	*Drymaria diandra* *Potentilla kleiniana* *Fimbristylis* sp2 *Carex* sp *Borreria alata*		*Dactyloctenium aegyptium*		*Leguminosae* sp *Cymbopogon flexuosus* *Setaria pallidefusca* *Erigeron canadensis* *Cucurbita* sp	
	Crotalaria sp *Rungia parviflora*				*Isachne albens* *Scrophulariaceae* sp	

[1]Numata's summed dominant ratio (SDR) averaged across sites;[2] number of sites where species was present

Table A2: Plant communities at locations from 1000-2000m, including those species unique to each site, along with SDR cover classes (adapted from Tsuchida 1987, 1991)

Species	Wangdue 1350m (5 sites)		Kurthung 1300m (4 sites)		Zhemgang 1870m (4 sites)		Mongar 1680m (5 sites)	
	SDR (%)[1]	Sites[2]	SDR (%)	Sites	SDR (%)	Sites	SDR (%)	Sites
Chrysopogon aciculatus	58.6	4	55	3	25	1	80.2	5
Cynodon dactylon	70	5	41.75	3	50	3	29.4	4
Artemesia indica	7	1	25	3	30	2	5.6	1
Spilanthes iabadicensis	13.6	1	7.5	1	22	2	7	1
Ageratum conyzoides	27	3			20	2	6	2
Eragrostis tenella	19	3	16.25	2			6.2	1
Sporobolus fertilis	4	1			17	1	15	2
Plantago erosa	11.6	1			5	2	15	4
Euphorbia hirta	6.4	1	12	3			2	1
Fimbristylis sp	13	1			6.8	1	7.6	4
Potentilla kleiniana	8.4	1			1.3	1	7.6	2
Eragrostis nigra					56	4	16.4	3
Heteropogon contortus	39.8	4	14.5	1				
Paspalum scrobiculatum	14.4	1			37	2		
Cassia tora	20.8	2	13.75	2				
Pteridium aquilinum	8.6	1			20	1		
Rubus ellipticus	5	1			19	2		
Centella asiatica					18	2	5.4	3
Rumex nepalensis	16.4	1			3.5	1		
Dactyloctenium aegypticum	5.4	1	12.5	2				
Setaria pallidefusca					13.3	3	3.5	1
Lespedeza cuneata	7	1	9.25	1				
Anaphalis margaritacea					13	1	3.6	1
Arthraxon sp					5.2	1	10.8	3
Stellaria media	12.4	1			3	1		
Leguminosae sp					13	2	1.4	1
Oxalis corniculata					8.8	2	4.8	3
Eleusine indica			3	1	3	1		
Geranium nepalense					2.3	1	4	1
Species unique to	**Wangdue**		**Kurthung**		**Zhemgang**		**Mongar**	
SDR > 20%	*Digitaria cruciata*						*Paspalum* sp	
11-20%	*Desmodium heterocarpon* *Siegesbeckia orientalis* *Imperata cylindrica* *Xanthium stumarium* *Cynoglossum zeylanicum* *Potentilla* sp		*Digitaris setigera* *Ischaemum rugosum* *Saccharum spontanium* *Eragrostis* sp		*Arundinella hookeri* *Digitaria violascens* *Verbena* sp *Osbeckia* sp *Crotalaria cytisoides*		*Digitaria* sp	

Table A2 Cont.....

3-10 %	*Euphorbia humifusa* *Emilia sonchifolia*** *Cymbopogon flexuosus* *Eupatorium adenophorum* *Jasminum* sp *Adenostemma lavenia* *Tridax procumbens*	*Sida* sp *Zornia gibbosa* *Eragrostis unioloides* *Bidens* sp *Amaranthus* sp	*Potentilla fragarioides* *Geranium procurrens* *Cosmos* sp *Lamium amplexicaule* *Elsholtzia strobilifera* *Anaphalis busua* *Desmodium* sp	*Verbena officinalis* *Sporobolus diander* *Desmodium multiflorum* *Bidens pilosa* *Potentilla fulgens* *Taraxacum* sp *Agrostis inaequiglumis*

[1]Numata's summed dominant ratio (SDR) averaged across sites ; [2] number of sites where species was present

Table A3: Plant communities at locations from 2000-3000 m, including those species unique to each site, along with SDR cover classes (adapted from Tsuchida 1987, 1991)

Species	Thimphu 2370m (6 sites)		Trongsa 2200-2400m (4 sites)		Sengor 3000m (3 sites)	
	SDR (%)[1]	Sites[2]	SDR (%)	Sites	SDR (%)	Sites
Eragrostis nigra	30.8	5	22	3	20	1
Arundinella hookeri	0.8	1	36.5	3	16	1
Fimbristylis sp	5.8	4	6.8	1	31	2
Helictotrichon parviflorum	8.8	1	18.3	2	16	1
Prunella vulgaris	1.2	1	7.8	2	32	3
Chrysopogon aciculatus	54.5	5	25.3	2		
Sporobolus fertilis	7.5	3	26	2		
Anaphalis margaritacea			30.3	4	8	2
Primula capitata			2	1	35	2
Potentilla fulgens			10.5	3	19	1
Artemisia indica	7.8	2	20	3		
Miscanthus nudipes	10.7	2	13	1		
Hypericum sp	1	1			20	2
Setaria sp	3	2	17.8	1		
Carex nubigena	15.7	3			1.7	1
Cynodon dactylon	10	3	6.3	1		
Pycreus sp	2.3	2	12.5	1		
Myriactis nepalensis			6.2	1	4.7	1
Rumex nepalensis	7.2	1			3.3	1
Smithia ciliata	4.7	1	5.3	2		
Cotoneaster microphyllus			5	1	4.7	1
Stellaria vestita	1.7	1	6.3	2		
Poa annua	1.7	1			1.7	1
Plantago erosa	0.8	1	1	1		

Species unique to	Thimphu	Trongsa	Sengor
SDR > 20 %	-	*Eularia* sp	*Moss* *Carex albata* *Agrostis nervosa* *Senecio chrysanthemoides*
11-20 %	*Digitaria stricta*	*Centella asiatica* *Spilanthus iabadicensis* *Viburnum coriaceum* *Salix* sp	*Eriocaulon* sp *Coelachne simpliciuscula* *Elymus sikkimensis* *Luzula* sp
3-10 %	*Erigeron canadensis* *Cosmos* sp *Galinsoga parviflora* *Cassia mimosoides* *Cyperus* sp *Paspalum scrobiculatum*	*Juncus* sp *Agrimonia pilosa* *Circium* sp *Gnaphalium* sp *Quercus* sp *Imperata cylindrica* *Desmodium multiflorum* *Euphrasia* sp *Pimpinella* sp	*Aster* sp *Iris* sp *Cyanotis vaga* *Persicaria nepalensis* *Halenia elliptica* *Solanum* sp *Fimbristylis* sp *Hemiphragma* sp *Heterophyllus* sp

[1]Numata's summed dominant ratio (SDR) averaged across sites ;[2] number of sites where species was present

Table A4: Plant communities at locations from 3000-4000 m, including those species unique to each site, along with SDR cover classes (adapted from Tsuchida 1987, 1991)

Species	Kurbang 3300-3500m (3 sites)		Morathang 3580m (3 sites)		Gorseum 3120m (3 sites)	
	SDR (%)[1]	Sites[2]	SDR (%)	Sites	SDR (%)	Sites
Juncus sp	22.7	1	25.0	1	28.3	1
Agrostis nervosa	17.0	1	12.7	1	28.0	2
Prunella vurgaris	28.7	3	21.3	3	3.7	1
Carex nubigena	9.0	1	29.0	2	11.7	3
Senecio chrysanthemoides	6.0	1	6.0	1	26.0	2
Poa sp	6.0	1	17.0	1	5.7	1
Potentilla fulgens	6.0	1			62.3	3
Anaphalis margaritacea	2.0	1			46.7	3
Arundinaria sp	33.3	1			13.3	1
Agrostis pilosula	22.7	1	12.7	1		
Carex sp	33.3	1	4.3	1		
Aconogonon molle	17.0	1	17.3	1		
Agrostis inaequiglumis	21.0	1	11.3	1		
Elsholtzia strobilifera	4.7	1			26.7	2
Berberis umbellata	14.0	1			14.0	1
Umbelliferae sp	3.0	1			23.0	2
Plantago erosa	7.0	2	19.3	1		
Epilobium wallichianum	8.7	1	12.3	2		
Potentilla fragarioides	12.3	2	2.3	1		
Geranium donianum	4.7	1	5.7	1		
Species unique to	**Kurbang**		**Morathang**		**Gorseum**	
SDR > 20 %	*Primula capitata* *Rumex nepalensis*		*Myricaria rosea* *Primula* sp		*Festuca undata* *Bromus staintonii*	
11-20 %	*Juniperus recurva* *Persicaria runcinata* *Fern* *Kobresia duthiei* *Glyceria* sp *Agrostis myriantha*		*Anaphalis triplinervis* *Festuca* sp *Trisetum spicatum*		*Euphrasia* sp *Cupressus torulosa* *Fimbristylis* sp *Artemisia indica* *Eragrostis nigra* *Myriactis nepalensis*	
3-10 %	*Deyeuxia scabrescens* *Strobilanthes* sp *Festuca ovina* *Gallium asperifolium*		*Persicaria nepalensis* *Euphrasia* sp *Glyceria tonglensis* *Orchidaceae* sp *Parochetus communis* *Saxifraga sphaeradena* *Stelaria vestita*		*Agrostis* sp *Arundinella hookeri* *Brachypodium* sp *Elymus sikkimensis* *Halenia elliptica* *Helictotrichon parviflorum*	

[1] Numata's summed dominant ratio (SDR) averaged across sites; [2] number of sites where species was present

Table A5: Plant communities at locations above 4,000m, including those species unique to each site, along with SDR cover classes (adapted from Tsuchida 1987, 1991)

Species	Umatatsho 4,340-4,500m (3 sites)		Yango 4,800-4,900m (5 sites)		Geschewoma 4,600-4,800m (4 sites)	
	SDR (%)[1]	Sites[2]	SDR (%)	Sites	SDR (%)	Sites
Potentilla microphylla	50.3	3	23.2	5	21	4
Kobreasia duthiei	22.3	1	46	5	34	4
Kobreasia royleana	25.3	2	20.8	3	35	4
Poa sp	34.3	2	10	1	23	2
Moss	18.0	2	26.8	4	36	5
Agroatis inaequiglumis	46.7	3	26.6	2		
Taraxacum sp	11.7	1	7	1		
Juncus sp	26.3	2	35.6	4		
Gentiana depressa			12	3	16	2
Umbelliferae sp	6.0	1			5.2	2
Bistorta macrophylla			23.2	5	9.8	3
Carex sp	5.0	1	12	2	15	2
Berberis sp			6	1	15	1
Swertia sp			2.8	2	9.4	1
Potentilla saundersiana			10	1	20	1
Gentiana sp			3.8	2	14	1
Deyeuxia pulchella	7.0	1	10.6	2		
Lomatogonium sp			4.6	1	11	1
Festuca ovina			10.6	1	33	4
Potentilla cuneata	3.7	2	9.6	2		
Primula sp			10.8	2	11	3
Anaphalis triplinervis			8.8	2	17	4
Agrostis sp			8	1	7.8	1
Rhododendron anthopogon			11.2	2	25	2
Festuca sp	29.0	3	24.6	3		
Gentiana algida	15.3	3	5	1		
Species unique to	**Umatatsho**		**Yango**		**Geschewoma**	
SDR > 20 % ()			*Rhododendron nivale*		*Rhodiola* sp *Arenaria polytrichoides*	
11-20 %	*Persicaria runcinata*		*Leontopodium* sp *Trisetum spicatum* *Arenaria* sp		*Rheum nobile*	
3-10 %	*Chrysosplenium* sp *Poa annua* *Bistorta vivipara* *Pedicularis siphonantha*		*Ephedra gerardiana* *Ranunculus brotherusii* *Cassiope fastigiata* *Aconitum* sp *Lonicera myrtillus* *Deyeuxia* sp		*Geranium donianum* *Cortiella hookeri* *Saussurea hookeri*	

[1] Numata's summed dominant ratio (SDR) averaged across sites; [2] number of sites where species was present

Species Tested for Use as Fodder

Tables A6 to A8 show the grass, legume and other species tested for use as fodder and the stage of testing. The stages of testing reflected are: initial testing in observation nurseries in research station plots; on-farm testing of material that performs well; and promotion of suitable material in the extension programme.

The references referred to are 1 - Roder 1983c ; 2 - AHD 1990; 3 - Rumball 1990; 4 - RNR-RC Jakar 1997c; 5 - Roder 1982c; 6 - Gibson 1989b; 7 - RNR RC-Jakar 1998; 8 - RNR RC-Jakar 1997d

Table A6: Grass species tested for use as livestock fodder

Species	Year	Cultivars	Stage of testing	Ref.
Agropyron desertorum	1980	1	Observation nursery	1
Agropyron elongatum	1980	1	Observation nursery	1
Agropyron inerme	1980	1	Observation nursery	1
Agropyron intermedium	1980	1	Observation nursery	1
Agropyron smithii	1980	1	Observation nursery	1
Agropyron trachycaulum	1980	1	Observation nursery	1
Agrostis alba	1987	1	Observation nursery	2
Agrostis tenuis	1980	3	On-farm	1
Alopecurus pratensis	1990	1	On-farm	2
Alopecurus arundinaceus	1988	1	On-farm	3
Andropogon gayanus	1996	1	On-farm	4
Andropogon gerardi	1996	2	Observation nursery	4
Arrhenatherum elatius	1975	1	Observation nursery	1
Brachiaria brizantha	1996	2	On-farm	4
Brachiaria decumbens	<1982	2	Extension	5
Brachiaria insculpta	1996	1	Observation nursery	4
Brachiaria humidicola	1996	1	Observation nursery	4
Brachiaria pertusa	1996	1	Observation nursery	4
Brachiaria ruziziensis	1988	2	Extension	6
Bothriochloa caucasica	1988	1	Observation nursery	3
Bothriochloa ischaemum	1988	3	Observation nursery	3
Bromus catharticus	1980	2	On-farm	1
Bromus erectus	1988	1	Observation nursery	2
Bromus inermis	1980	3	On-farm	1
Cenchrus ciliaris	<1982	5	Observation nursery	5
Chloris gayana	<1982	4	Observation nursery	5
Cynosurus cristatus	1980	1	Observation nursery	1
Dactylis glomerata	1974	30	Extension	1
Digitaria milanjiana	1988	1	Observation nursery	6
Digitaria natalensis	1996	1	Observation nursery	4
Digitaria setivalva	1996	1	Observation nursery	4
Digitaria smutsii	1988	1	Observation nursery	6
Echinochloa utilis	1988	1	Observation nursery	6
Elymus junceus	1980	1	Observation nursery	1

Table A6 Cont.....

Species	Year	Cultivars	Stage of testing	Ref.
Elymus dauricus	1988	1	Observation nursery	3
Elymus sibiricus	1988	1	Observation nursery	3
Festuca arundinacea	1978	20	Extension	1
Festuca ovina	1989	1	Observation nursery	2
Festuca pratensis	1974	8	On-farm	1
Festuca rubra	1975	8	On-farm	1
Holcus lanatus	1981	3	Observation nursery	1
Lolium multiflorum	1974	20	Extension	1
Lolium perenne	1974	25	On-farm	1
L. multiflorum x perenne	1979	8	Observation nursery	1
Melinis minutiflora	< 1982	1	Extension	5
Panicum antidotale	< 1982	1	Observation nursery	5
Panicum coloratum	1996	2	Observation nursery	4
Panicum maximum	< 1982	8	On-farm	5
Panicum virgatum	1988	8	Observation nursery	3
Paspalum atratum	1996	2	On-farm	4
Paspalum dilatatum	< 1982	3	Observation nursery	5
Paspalum guenoarum	1996	2	Observation nursery	4
Paspalum notatum	1981	1	Observation nursery	1
Pennisetum clandestinum	< 1975	3	Extension	
Phalaris arundinacea	1989	1	Observation nursery	2
Phalaris tuberosa	1979	1	Observation nursery	1
Phleum pratense	1974	10	Observation nursery	1
Poa compressa	1989	1	Observation nursery	2
Poa pratensis	1975	10	On-farm	1
Secale cereale	1974	4	On-farm	1
Secale montanum	1980	2	Observation nursery	1
Setaria incrassata	1988	1	Observation nursery	6
Setaria sphacelata	< 1982	3	On-farm	5
Sorghastrum nutans	1988	5	Observation nursery	6
Sorghum bicolor	1988	1	Observation nursery	6
Sorghum sudanense	1988	2	Observation nursery	6
Trisetum flavescens	1979	1	Observation nursery	1
Urochloa mosambicensis	1996	1	Observation nursery	4
Urochloa ologotricha	1996	1	Observation nursery	4

Table A7: Legume species tested for use as livestock fodder				
Species	**Year**	**Cultivars**	**Highest test level**	**Ref.**
Acacia angustissima	1988	1	Observation nursery	6
Acacia villosa	1998	1	Observation nursery	7
Acacia mearnsii	1988	1	Observation nursery	6
Aeschynomene americana	1988	3	Observation nursery	6
Aeschynomene brasiliana	1996	3	Observation nursery	4
Aeschynomene elegans	1988	1	Observation nursery	6
Aeschynomene histrix	1996	3	Observation nursery	4
Aeschynomene villosa	1988	3	Observation nursery	6
Albizia chinensis	1989	1	Observation nursery	6
Alysicarpus glumaceus	1988	1	Observation nursery	6
Alysicarpus monilifer	1988	2	Observation nursery	6
Alysicarpus ovalifolius	1988	1	Observation nursery	6
Alysicarpus rugosus	1988	2	Observation nursery	6
Arachis pintoi	1989	4	On-farm and management studies	6
Astragalus cicer	1979	3	Observation nursery	1
Astragalus falcatus	1979	1	Observation nursery	1
Astragalus sinicus	1989	1	On-farm	8
Cajanus cajan	1989	15	On-farm (as tree fodder)	2
Calliandra calothyrsus	1989	1	Observation nursery	6
Canavalia brasiliensis	1998	1	Observation nursery	7
Canavalia ensiformis	1998	1	Observation nursery	7
Caragana arborescens	1981	1	Observation nursery	1
Centrosema acutifolium	1996	1	Observation nursery	4
Centrosema arenarium	1998	1	Observation nursery	7
Centrosema brasilianum	1998	1	Observation nursery	7
Centrosema macrocarpum	1996	1	Observation nursery	4
Centrosema pascuorum	1998	1	Observation nursery	7
Centrosema pubescens	1982	1	Observation nursery	5
Chamaecrista rotundifolia	1988	4	On-farm and establishment studies	6
Chamaecytisus palmensis	1981	1	Observation nursery	1
Chamaecytisus proliferus	1989	1	Observation nursery	6
Clitoria ternatea	1996	2	Observation nursery	4
Coronilla varia	1980	4	On-farm	1
Crotalaria anagyroides	1998	1	Observation nursery	7
Desmanthus virgatus	1996	4	Observation nursery	4
Desmodium discolor	1988	1	Observation nursery	3
Desmodium heterocarpon	1988	1	Observation nursery	6
Desmodium intortum	1982	3	Extension	5
Desmodium nicaraguense	1996	1	On-farm	4
Desmodium ovalifolium	1996	1	Observation nursery	4
Desmodium prostratum	1988	1	O. nursery	6
Desmodium rensonii	1996	1	On-farm	4
Desmodium salicifolium	1996	1	Observation nursery	4
Desmodium subserceum	1988	1	Observation nursery	2
Desmodium uncinatum	1982	1	Extension	5
Dorycnium hirsatum	1981	1	Observation nursery	6

Table A7 Cont.....

Species	Year	Cultivars	Stage of testing	Ref.
Flemingia macrophylla	1989	2	Observation nursery	6
Galactia striata	1996	1	Observation nursery	4
Galactia sp	1996	2	Observation nursery	4
Gleditsia triacanthos	1981	2	Observation nursery	1
Gliricidia sepium	1989	7	Observation nursery	6
Hedysarum coronarium	1980	2	Observation nursery	1
Hedysarum boreale	1980	2	Observation nursery	1
Lablab purpureus	1980	3	On-farm	5
Lathyrus cicera	1992	15	On-farm	8
Lathyrus latifolius	1980	2	Observation nursery	1
Lathyrus sylvestris	1980	1	Observation nursery	1
Lespedeza cuneata	1980	5	Observation nursery	1
Lespedeza cyrtobotrya	1989	1	Observation nursery	2
Lespedeza maximowiczii	1989	1	Observation nursery	2
Lespedeza sericea	1980	2	Observation nursery	1
Leucaena leucocephala	1978	3	Observation nursery	9
Leucaena pallida	1989	1	On-farm, extension	6
Leucaena diversifolia	1989	3	Observation nursery	6
Lotononis bainesii	1989	2	Observation nursery	1
Lotus angustissimus	1988	1	Observation nursery	4
Lotus corniculatus	1975	15	On-farm	1
Lotus pedunculatus	1979	8	On-farm	1
Lupinus angustifolus	1980	8	Observation nursery	10
Lupinus albus	1980	5	Observation nursery	10
Lupinus arboreus	1989	1	Observation nursery	2
Lupinus cosentinii	1996	1	Observation nursery	10
Lupinus hartwegii	1989	1	Observation nursery	2
Lupinus luteus	1980	4	Observation nursery	10
Lupinus nootkatensis	1989	1	Observation nursery	2
Lupinus mutabilis	1977	50	Management studies	10
Lupinus polyphyllus	1989	1	Observation nursery	2
Lupinus sativus	1996	7	Observation nursery	4
Macroptilium atropurpureum	<1982	1	Observation nursery	5
Macroptilium. gibbosifolium	1996	1	Observation nursery	4
Macroptilium gracile	1996	1	Observation nursery	4
Macrotyloma axillare	<1982	3	Observation nursery	5
Macrotyloma daltonii	1996	1	Observation nursery	4
Medicago arborea	1981	6	Observation nursery	1
Medicago coerulea	1981	1	Observation nursery	1
Medicago falcata	1980	4	Observation nursery	1
Medicago glutinosa	1979	1	Observation nursery	1
Medicago marina	1996	4	Observation nursery	1
Medicago media	1981	8	Observation nursery	1
Medicago polychroa	1981	1	Observation nursery	1
Medicago polimorpha	1989	2	Observation nursery	1

Table A7 Cont.....

Species	Year	Cultivars	Stage of testing	Ref.
Medicago sativa	1974	40	Extension	1
Medicago trautvetteri	1981	1	Observation nursery	1
Melilotus alba	1980	5	Observation nursery	1
Melilotus elegans	1996	2	Observation nursery	4
Melilotus neapolitana	1996	3	Observation nursery	4
Melilotus officinalis	1980	8	On-farm and establishment studies	1
Melilotus wvolgica	1981	1	Observation nursery	1
Mucuna pruriens	1996	1	On-farm	4
Neonotonia wightii	1980	4	Observation nursery	5
Onobrychis arenaria	1981	2	Observation nursery	1
Onobrychis caput-galli	1996	2	Observation nursery	4
Onobrychis crista-gally	1996	2	Observation nursery	4
Onobrychis transcaucasica	1981	1	Observation nursery	1
Onobrychis viciifolia	1974	5	Observation nursery	1
Pueraria lobota	1980	1	Observation nursery	1
Pueraria phaseoloides	1998	1	Observation nursery	7
Robina pseudoacacia	1975	2	Observation nursery	1
Sesbania rostrata	< 1990	1	Observation nursery	
Sesbania aculeata	< 1990	1	Observation nursery	
Sesbania sesban	< 1990	1	Observation nursery	
Stylosanthes capitata	1996	1	Observation nursery	4
Stylosanthes guianensis	< 1982	4	Extension	5
Stylosanthes hamata	< 1980	3	Observation nursery	5
Stylosantes scabra	< 1980	3	Observation nursery	5
Teline stenopetala	1989	1	Observation nursery	2
Teramnus uncinatus	1996	2	Observation nursery	4
Trifolium alexandrinum	1974	1	On-farm	1
Trifolium ambiguum	1980	11	Observation nursery	1
Trifolium arvense	1981	1	Observation nursery	1
Trifolium baccarinii	1988	1	Observation nursery	6
Trifolium badium	1988	1	Observation nursery	6
Trifolium burchellianum	1988	1	Observation nursery	6
Trifolium decorum	1988	1	Observation nursery	6
Trifolium dubium	1981	1	Observation nursery	1
Trifolium fragiferum	1980	2	Observation nursery	1
Trifolium hirtum	1996	1	Observation nursery	4
Trifolium hybridum	1974	4	Establishment studies	1
Trifolium incarnatum	1974	1	Management and establishment	1
Trifolium lugardii	1988	1	Observation nursery	6
Trifolium mattirolianum	1988	1	Observation nursery	6
Trifolium medium	1980	5	Observation nursery	1
Trifolium pichi-sermolli	1988	1	Observation nursery	6
Trifolium pratense	1968	20	On-farm	11
Trifolium polymorphum	1988	1	Observation nursery	6
Trifolium polystachyun	1988	1	Observation nursery	1

Table A7 Cont.....

Species	Year	Cultivars	Stage of testing	Ref.
Trifolium quatinium	1998	1	Observation nursery	7
Trifolium repens	1968	12	Extension	11
Trifolium resupinatum	1974	1	Observation nursery	1
Trifolium ruepellianum	1988	11	Seed production studies	6
Trifolium semipilosum	1979	3	Observation nursery	1
Trifolium steudneri	1988	1	Observation nursery	6
Trifolium tembense	1988	8	Observation nursery	6
Trifolium usambarense	1988	1	Observation nursery	6
Vicia dasycarpa	1981	1	Observation nursery	1
Vicia sativa	1974	18	Observation nursery	1
Vicia villosa	1974	20	On-farm, management studies	1
Vicia tenuifolia	1980	1	Observation nursery	1
Vigna luteola	1996	1	Observation nursery	4
Vigna oblongifolia	1996	1	Observation nursery	4
Vigna parkeri	1988	3	Observation nursery	6
Vigna racemosa	1996	1	Observation nursery	4
Vigna schimperi	1996	1	Observation nursery	4
Vigna trilobata	1988	1	Observation nursery	6
Vigna vexillata	1988	4	Observation nursery	6
Zornia latifolia	1996	1	Observation nursery	4
Zornia glabra	1996	1	Observation nursery	4

Table A8: Other species tested for use as livestock fodder

Species	Year	Cultivars	Highest test level	Ref.
Cichorium intybus	1987	1	Observation nursery	2
Helianthus tuberosus	1978	8	Extension, management studies	1
Brassica oleracea (Kale)	1979	3	Observation nursery	1
Brassica napus (Swede)	1979	3	On-farm	1
Brassica napus	1979	8	Observation nursery	1
Brassica rapa	1979	4	Observation nursery	1
Brassica pekinensis	1979	1	Observation nursery	1
Raphanus sativus	1979	1	Observation nursery	1
Phacelia tanacetifolia	1979	1	Observation nursery	1
Beta vulgaris	1975	4	On-farm	1

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