Forage research and development in the Kingdom of Bhutan

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The Himalayan Kingdom of Bhutan has an area of about 46,500 km^2 and a population of 0.6 million. Its mountainous topography was aptly described by an early visitor (Marakham 1876) as 'a succession of lofty and rugged mountains, separated by gorges and a few valleys somewhat wider than the generality of ravines.' The elevation ranges from about 200 m in the south to almost 8000 m in the north.

The climate is dominated by the monsoon with a dry winter season and high precipitation during June-September. Influenced by topography, elevation, and rainfall pattern, Bhutan has a wide variety of climatic conditions and, consequently, a wide diversity in vegetation and farming systems.

Agriculture is the main economy of the country. About 85% of the population live in rural areas and depend on agriculture. Due to the mountainous topography, only a very small percentage of the land is suitable for agriculture. Crops cultivated (in order of importance) are maize, rice, millet, wheat, buckwheat, potato, mustard, and barley (Table 1). Rice is cultivated on small terraces made on slopes with gradients up to 80%. Topography and market accessibility favour livestock production, especially in regions with elevations above 2000 m. Livestock production is traditionally an integrated part of the Bhutanese farming system.

Table 1. Land use and livestock statistics.

Land use[1]	Area ('000 ha)
Forest (x1000ha)	2904
Lowland rice (x1000ha)	39
Upland agriculture (maize, wheat, barley, buckwheat) (x1000ha)	182
Shifting cultivation (Tsheri and Pangshing) (x1000ha)	88
Horticulture plantations (apple, orange, cardamom) (x1000ha)	6
Natural pasture (x1000ha)	155
Improved pasture (x1000ha)	1
Livestock (1995 data)[b] (x1000 head)	1000
Cattle (x1000 head)	305
Buffalo (x1000 head)	1
Yak (x1000 head)	30
Equine (horse, mules, donkeys) (x1000 head)	26
Goat (x1000 head)	16
Sheep (x1000 head)	31

[1] Source: MOA, 1997; [b] Source: MOA 1995.

Research institutions

The Ministry of Agriculture was reorganized during the period 1993-95. Separate divisions were formed: 1) Research, Extension and Irrigation; 2) Crop and Livestock Service Division (mostly input supply); and 3) Forest Service Division (territorial forest

[1] Renewable Natural Resources Research Centre, Jakar, Bhutan.

management). Under the Research, Extension and Irrigation Division, four national renewable natural resources research centres (RNR-RCs) were established and given specific regional and national mandates (Table 2). Each research centre was assigned to lead one of the national programs that deal with field crops, horticulture, livestock and forestry. Additionally, the farming systems program under each centre also includes socio-economic, cross-sectoral, and other activities not directly associated with a single program.

Table 2. Existing research centres, mandates, and regions.

Research centre	National mandate	Region
Yusipang	Forest	Western Region
Bajo	Field crops	West Central Region
Jakar	Livestock	East Central Region
Kangma	Horticulture	Eastern Region

In its respective region, each centre is responsible for the implementation of all research activities. Besides the main task of importing, adapting, or generating technologies to be used in the extension programs, the centres are responsible for building up a pool of expertise and information and for supporting the extension and development programs by way of technical assistance, training, and general backstopping.

The National Livestock Research Program, coordinated by the Research Centre in Jakar, has been divided into 3 subprograms: breeding and management, feed and fodder, and health.

With the assumption that technologies under the subprograms breeding and management and health can, to a certain extent, be imported from other countries with little or no further adaptation, major emphasis is given to the subprogram feed and fodder with an allocation of 70-80% of the available resources (RNR-RC 1997).

Research needs, priorities, and constraints

Matching the limited resources available with the needs of the tremendously variable production systems and climates has and will always be a challenge. Rigorous priority setting and judicious planning are given due importance. In a recent attempt to prioritise research needs and opportunities, the identification of main nutritional limitations was given the highest priority (Table 3), followed by fodder produced from intensively managed permanent grasslands.

The same areas received top ranking when research priorities were set in the late 1980s. Compared with earlier rankings there was a shift toward fodder resources in integrated systems. Similarly, crop residues were given more importance. This is largely attributed to the change in the research system. Through the integration of crop, horticulture, livestock, and forestry research, more emphasis is given to fodder production in crop or horticulture systems.

Regional priorities deviate from national priorities. At higher elevations, extensively managed permanent grasslands will have priority, whereas at lower elevations, arable fodders, tree fodders, and crop residues become important. Regional research priorities, needs, and opportunities are currently reviewed by the newly formed research centres.

Table 3. Ranking of research priorities at the national level[1].

Rank	Area of research
1	Identification of main nutritional limitations to animal production (seasonal fodder production, deficiencies in energy/protein/minerals, etc.).
2	Intensively managed permanent grassland (small plots in the vicinity of settlements, also includes orchards).
3	Arable fodder (in rotation or in combination with annual crops, winter fodder) for fodder, soil improvement, and/or soil conservation.
4	Extensively managed permanent grassland (range land).
4	Tree fodders, agroforestry and silvopastoral systems.
4	Use of crop residues and by-products (rice straw, maize stems, buckwheat stems, home brewing).
5	Technology development to support various programs (seed production, fodder conservation, etc.).
5	Grazing effects on forest systems.
6	Social and cultural aspects (migration, culling of unproductive animals, land ownership, communal agreements on protection of crops, etc.).

[1] Source: RNR-RC 1996.

A review of earlier research activities showed that the main constraint was the lack of rigorous priority setting (Table 4). Insufficient interaction with farmers and herders and poor representation of target environments as well as insufficient academic background of research personnel were considered the second most important constraints.

Table 4. Constraints to successful research in feed and fodder[1].

Rank	Constraint/limitation
1	Lack of focus or realistic identification of research needs
2	Insufficient interaction with farmers and herders and poor representation of target environments
2	Insufficient academic background of research personnel
3	Insufficient access to information
3	Insufficient research personnel
4	Wrong priorities
5	Most experimental activities limited to on-station work
6	Lack of coordination with extension activities
7	Lack of motivation of Bhutanese research personnel
7	Lack of fund
8	Lack of equipment
9	Too much dependence on expatriate advice
10	Insufficient support by the Ministry
11	Too much time absorbed in administrative work

[1] Source: RNR-RC, 1996.

Current research activities

All four research centres are strongly committed to regional research activities under the feed and fodder subprogram. Activities largely focus on:

- Description of resources and their management.
- Monitoring trends in the resource base and production.
- Identification and import of pertinent available information and technologies.
- Adaptation of technologies.

These activities are carried out in three sub-projects (Table 5). In addition, various activities are conducted in collaboration with other programs (forestry, field crops and horticulture).

Field work is done on-station and on-farm, with various levels of farmers' participation. Depending on the objectives of the individual activity, attempts are made to include extensionists and farmers or herders at all stages of the technology development and adaptation process.

Table 5. Sub-projects under the feed and fodder subprogram[1].

Subproject	Purpose/objective
Description of past and present management, monitoring trends	• Document past research and development activities • Describe existing fodder resource in terms of their management and potential • Monitor trends in resource quality and production
Genetic evaluation and improvement	• Characterize native grassland and fodder species • Import and evaluate exotic species
Production management	• Verify/adapt/develop technologies to optimise production and improve production efficiency and/or optimise synergistic effects between fodder production and other components

[1] Source: RNR-RC (1997).

Past and present management systems and monitoring trends

The extreme variations in climate, soils, and topography and the resulting adaptations by farmers and herders result in a huge range in vegetation, fodder sources, and production systems. Documenting fodder resources and existing management practices is thus a tremendous challenge for the small research team. Taking on the challenge, a process was initiated in 1996 to:

- Review past fodder research and development efforts.
- Document existing and potential fodder resources, farmers' practices, nutritional constraints to livestock production and quality of existing fodder.
- Generate information on farmers' practices, effect of management interventions, and productivity of natural grasslands.

The information collected and synthesized will provide inputs for planning and policy decisions and will also serve as basis for planning future research activities.

With increasing confidence in the accumulated base line information, monitoring trends in the resource base is gradually becoming more important. Considering the fragility of the grassland resources and the potentially harmful effects any management interactions may have on biodiversity, as well as on forest, water, and agricultural resources, it is important to build up mechanisms and develop key indicators which can quantify trends and changes over time.

Genetic evaluation and improvement

The species selected in the early phase of the fodder development program have many positive properties and have shown good potential over a wide range of prevailing conditions. There is, however, an urgent need to select additional species for

- All environments in the subtropical regions (woody and herbaceous).
- Temperate legumes with better adaptation to P and moisture stress.
- Fodder species providing winter feed for temperate and subtropical regions (woody and herbaceous).
- Species, especially legumes, for fodder production in cropping systems with field crops.

- Species for soil and moisture conservation (woody and herbaceous), soil cover, green manure, and/or weed suppression.

Native and exotic materials are included in the program. Emphasis is laid on the acquisition and testing of plant materials to be used in integrated field crop, horticulture, or forestry systems and for soil conservation.

Production management

The subproject on production management includes a wide range of activities with emphasis on establishment, soil fertility management, seed production, and winter feed (Table 6).

Cross-sectoral activities

Various silvopastoral studies focusing on fodder and timber production and the interaction of the two are carried out in collaboration with the forestry program.

Similarly several studies focus on systems which integrate fodder production in apple or citrus production systems.

Table 6. Ongoing activities in sub-project 3: Production Management.

Subproject 3	Activity
Establishment	• Studies of temperate herbaceous species in bamboo-dominated grassland focusing on species, establishment methods, and P effects. • Studies of subtropical species in maize and rice systems with main focus on species, effect of planting date relative to crop maturity, and planting method. • Nursery methods for *Ficus roxburghii.*
Management	• Effects of fertiliser (N and P) and cutting interval effects on yield and species composition of temperate grassland systems. • Willow in combination with herbaceous fodder: studies evaluating the effect of plant density and plant height on dry matter production of both components of the system.
Seed production	• Various studies evaluating the effect of location, plant density and irrigation. • Effects of other management interventions on *Lotus pedunculatus* and Greenleaf *Desmodium* and *Lucerne* seed production (aim is to develop technologies that will result in economically viable seed production of these species).
Fodder preservation – winter fodder	• Testing of selected winter fodder species in potato, maize and rice systems. • Development of systems to optimise use of existing fodder resources with studies focusing on deferred grazing, use of willow leaves, and the preservation of arable fodder biomass in the field.

Selected research findings

Past research activities have identified or generated a wide range of information and technologies:

- Description of major fodder resources and farmers' management practices.
- Characterisation of selected native grassland and fodder species.
- Selection of suitable herbaceous and woody fodder species for major environments and farming systems.
- Establishment methods (including inoculation) for temperate and subtropical species.
- Quantification of the effects of fertilisers (mainly P and N) on selected species and mixture of species and development of recommendations for fertiliser use.
- Evaluations of effects of micronutrients on establishment and dry matter production
- Development of appropriate seed production technologies for selected grass and legume species.

In this section, selected results from these activities are described in detail.

Introduction and initial screening of exotic species

Planned germplasm introduction and evaluation started in the early seventies. Over the past two decades, more than 150 legume species and 70 grass species have been introduced and evaluated for their fodder production potential across a wide range of environments. Substantial information was generated on the performance of temperate species over several locations and years (Table 7). With a few exceptions, white clover and cocksfoot produced the highest yields. Good yields were also observed in lotus, red clover, Lucerne, tall fescue, and Italian rye grass.

Table 7. Yield of selected temperate perennial fodder species[1].

Location	Batbalathang, Bumthang	Karsumphe, Bumthang
Elevation	2,650 m	2,700 m
Period/duration	1980-82 (3 yr)	1983-85 (3 yr)
	(legume yield relative to white clover)	
White clover	100	100
Lathyrus silvestris	-	43
Lotus corniculatus	92	24
Lotus pedunculatus	111	17
Medicago glutinosa	94	-
Medicago media	-	66
Medicago sativa	72	87
Trifolium hybridum	76	-
Trifolium pretense	103	84
Trifolium semipilosum	89	-
Vicia tenuifolia	-	53
	(grass yield relative to cocksfoot)	
Cocksfoot	100	100
Arrhenatherum elatior	79	-
Festuca arundinacea	105	96
Festuca pratensis	93	-
Festuca rubra	87	99
Lolium multiflorum	112	93
Lolium perenne	78	-
Paspalum notatum	-	76
Poa pratensis	73	98
Phleum pratense	86	-

[1] Source: RNR-RC (1998).

Species recommended for dissemination

A considerable number of annual and perennial species and varieties have been recommended for fodder production in specific environments (Table 8). Some of them have been included in extension programs, while others are still under investigation or have been discarded because of seed production problems, limited potential for Bhutan, or other reasons.

Table 8. Species recommended for use in Bhutan[1].

Species	Year[2]	Area (ha)	Present status
Annual species			
Oat	<1975	<100	Recommended for winter feed
Fodder beet	1982	<10	On-farm evaluation
Winter vetch	1978	<5	
Swede	1982	-	On-farm evaluation
Kale	1982	-	
Field pea	1978	-	
Herbaceous perennials			
White clover	1978	100,000	Extension program since 1978
Cocksfoot	1978	20,000	
Italian ryegrass	1978	15,000	
Tall fescue	1982	15,000	
Kikuyu grass	1982	2000	Not multiplied, weed problems
Napier grass	1982	500	Extension program since 1980?
Greenleaf desmodium		<500	Provisionally in extension
Lotus	1979	<50	program for limited periods
Lucerne	1978	<5	Problems in seed production
Red clover	1978	-	Seed production studies
Stylo (*S. guianensis*)	1982	<50	On-farm evaluation
Red fescue	1982	<10	
Silverleaf desmodium	1982	-	
Kentucky blue grass		-	
Guinea grass	1982	-	
Setaria (*S. sphacelata*)	1982	-	
Crown vetch	1982	-	Under observation
Glenn joint vetch	1988		
T. ruepellianum	1988		
Woody perennials[3]			
Willow	1981	100	Extension program since 1982
Leucaena leucocephala		<5	
Ficus roxburghii	1982	5000	
Ficus nemoralis	1982	<100	
Bauhinia purpurea	1982	<100	
Bauhinia variegata	1982	<100	
Artocarpus lakoocha	1982	<100	
Brassaiopsis hainla	1982	<100	
Lytsea polyantha,	1982	<100	
Saurauia nepaulensis	1982	<100	
Prunus cerasoides	1982		

[1] Source: RNR-RC Jakar (1998).
[2] Year when species was first recommended for extension.
[3] Area for woody perennials based on 200 tree/ha.

Experiences with white clover

White clover is the most widely used exotic fodder species in Bhutan. The first recorded introductions were made in 1970 (RNR-RC 1998). Within a relatively short time, white clover has proven to be the most suitable legume for grassland improvement over a wide range of conditions within the altitude belt of 2000-4000 m (Gyamtshso 1996). Its introduction was, however, only successful with inoculation and P application. White clover not only increased dry matter yield but also substantially increased fodder quality and potential milk production (Tables 9 and 10).

The exceptionally successful introduction of white clover has alarmed among various parties. While some are mainly concerned by its bloat-inducing property, others have called for caution in future extension programs because they see it as a serious weed, even considering it as a threat to the existing biodiversity (Roder 1997). Although this may be largely an overreaction, there clearly is a need to reassess the status of white clover in future fodder development activities and to identify techniques and species that

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

Table 9. Fodder quality of white clover compared with local species.

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

Source: RNR-RC (1998).

Table 10. Milk production potential of selected fodder sources.

Fodder type	Milk potential (kg/animal)
Local pasture winter	<0.5
Local pasture summer	8
Local pasture with white clover	15
Hay from local pasture	2
Hay from white clover/grass mixture	14

Source: RNR-RC (1998).

Extension

Modest extension activities aimed at increasing fodder production or quality started in the late sixties or early seventies. Early activities were sporadic and generally dependent on projects which are limited in time and space. Most of the development centres initiated in the late 1960s such as the Samchi farm, Lingmethang farm, Gogona farm, and Bondey farm had, at some stage, promoted fodder species (RNR-RC 1998). Although these activities had little impact, the lessons learned from these experiences provided valuable inputs for the later programs.

Extension network

The Animal Husbandry Department begun to build up a network of extension centres in the seventies. These centres located at the Gewog level (subunit of a district comprising 150-800 households) were generally staffed with veterinary compounders. The main objectives are to provide health care and to supervise crossbreeding activities. Extension workers (pasture assistants) for fodder development were trained from 1978 onwards. While some of these fodder specialists were placed at Gewog levels, others were attached to the district headquarters.

Extension programmes

Promotion of perennial herbaceous fodder species in temperate regions

The earliest documented and sustained extension activities focusing on fodder development started in Bumthang. District in 1978 (RNR-RC 1998). The package of practices recommended in 1978, included:

- Species and seed rate (kg/ha): white clover, 4 kg; Italian rye grass, 8 kg; cocksfoot, 4 kg or tall fescue, 4 kg.
- Inoculation: clover seed were inoculated and coated with gum arabic and rock phosphate.
- Subsidies: seed were charged a nominal rate of Nu 2.0 kg-1 (approximately 10% of the production cost). Phosphate fertiliser was provided free of cost.
- Establishment: undersowing into sweet buckwheat was recommended as the preferred method. Other establishment methods recommended were seeding after cultivation or transplanting white clover without cultivation.
- Management: grazing and cut-and-carry were recommended. Scythes were introduced and distributed at subsidized rates.
- Preservation: winter feed preservation through hay or silo making was recommended. Simple pit silo systems were introduced.

This package of practices became the model for nationwide extension programs promoted by the Department of Animal Husbandry, with the first countrywide activities initiated in 1978. Minor changes introduced over the years included the following:

- With more cocksfoot and tall fescue seed available, it became possible to replace some of the Italian rye grass seed by these species.
- Seed costs were fully subsidized from 1983 onward.
- Fertiliser subsidies were discontinued in 1996.

An early assessment after 3 years of field activities mentioned the following problems (Roder 1981):

- Extreme variations in climate exist.
- Some ambiguity in the rules and regulations regarding grazing land are not resolved.
- Farmers are not motivated enough as the idea of cultivating fodder is new to them and no examples are available.
- High phosphate inputs are required.
- Very expensive inputs in the form of seeds are given to farmers free or at nominal cost, resulting in farmers' complacency not motivated to optimise coverage and establishment success).
- Inoculation failures are common due to poor inoculum quality.

Promotion of herbaceous fodder species in subtropical regions

Because seed and suitable methodologies are lacking the extension activities in subtropical regions were less successful. The species recommended changed with every plan period. The species recommended were (RNR-RC, 1998):

- Fifth plan: Kikuyu grass, Guinea grass, *Setaria sphacelata*, Rhodes grass, and Napier, Silverleaf desmodium, Glycine, and *Stylosanthes guianensis*.
- Sixth and seventh plan: Signal grass, Molasses grass, Guinea grass, *Setaria sphacelata*, Greenleaf desmodium, Silverleaf desmodium, Glycine, centro (*Centrosema pubescens*), siratro (*Macroptilium atropurpureum*), and *Stylosanthes guianensis*.

A review carried out in 1992 (Wangdi 1992) concluded that the main achievement made in subtropical areas was the creation an awareness for fodder development. It was observed that many sites had reverted back to weeds or shrubs. The main constraints listed were wild boar damage, overgrazing by wild animals, fencing problems, weed dominance and failure of establishment.

Promotion of tree fodder or woody species

Fodder tree extension activities were launched in 1982, with local fodder tree species (RNR-RC 1998). Farmers were advised to plant the following species: *Artocarpus lakoocha, Bauhinia variegata, Bauhinia purpurea, Lytsea polyantha, Ficus roxburghii, Ficus nemoralis, Brassaiopsis hainla, Saurauia napaulensis, Prunus creasoides* and willow. During the fifth plan, the farmers were paid US$ 0.012 as subsidy for each tree planted.

The only exotic fodder tree species recommended and distributed to farmers were Leucaena (*Leucaena leucocephala*) and *Robina pseudoacaicia* (RNR-RC 1998). The acceptance of these exotic species with farmers was, however, marginal at best. Psyllid infestation on Leucaena was observed at various locations.

The number of species recommended was reduced for the sixth plan to *Artocarpus lakoocha, B. variegata, B. purpurea, F. roxburghii, F. cunia, F. lakoor* and *Celtis australis.* Where suitable, farmers show a strong preference for *F. roxburghii.* This species is preferred for its wide adaptation, good biomass yield, availability during the dry season, and relatively good fodder quality (Tshering et al. 1997).

Paddy straw treatment, urea molasses block

Urea treatment of paddy straw was an important component of the extension program during the sixth and part of the seventh plan. Farmers were given free urea and training on treatment methods. An extension booklet was issued in 1987 (RNR-RC 1998). The advantages of urea treatment were supposed to include higher palatability and intake, better digestibility, higher N intake (from the urea) and reduction of liver fluke infestations.

Following a survey carried out in 1996, the technology was, however, not adapted. This in spite of the fact that almost all rice growers feed paddy straw to their cattle and consider liver fluke as a serious problem. The reasons cited for non-adoption include reduced intake, additional labour required and urea cost.

Impact of extension activities

Based on the progress reports the following were achieved through the extension activities during the fifth, sixth and seventh plan period (1982-1997):

- Pasture development: 34,000 acres.
- Fodder trees planted: 735,819 trees.

- Large coverage for paddy straw treatment (>50% of rice-growing households in selected districts.

The impact of these activities can be quantified at different levels: dry matter production, fodder quality, livestock production, socio-economic issues, and environment (Table 11).

Table 11. Impact of fodder development activities[1].

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

[1] Estimates by the author.

Impact on dry matter production

On a national level, the impact of fodder development activities on total dry matter production may be negligible. A recent estimate (RNR-RC 1998) puts additional dry matter production at would be about 15,000 t annually, sufficient to feed 1800 animals or about 0.5% of the total population of large ruminants.

Impact on nutritional quality

The impact of subtropical herbaceous fodder species and tree fodder in general on the nutritional quality of the diet is negligible. In temperate regions, the introduction of white clover, however, has resulted in a substantial increase in fodder quality in the wet and dry season. White clover has spread through the grazing animals 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 will substantially increase the quality of the fodder. It is largely through this increased fodder quality that the milk potential of crossbreed animals can be realized (Tables 9 and 10).

Impact on winter fodder

Tree fodder species are almost exclusively used for winter fodder. Herbaceous fodder species contribute substantially towards improved winter fodder quality and quantity. The traditional winter fodder such as paddy straw, buckwheat straw, native pasture and tree fodder leaves are all of very poor quality. Most of them are insufficient to even maintain the body weight of large ruminants. Small improvements in the quality of winter fodder will have substantial impact on infertility problems, mortality and production over the entire season.

Impact on animal production

The number of animals (yak and cattle) increased from 165,000 in 1976 (review undated) to 335,000 in 1995 (MOA 1995). We can assume that a 100% increase in livestock number resulted in a 100% increase in feed requirement. The increased requirement was largely covered by traditional fodder resources. Improved feed availability and quality in the dry season has, however, contributed substantially to make this tremendous increase in livestock number possible. The impact of fodder development on animal production is mainly realized in terms of change in seasonal draft availability and increased milk production.

Impact on migration

The traditional system of cattle migration to lower elevations during the dry/cold winter period has many disadvantages including spread of livestock diseases, limited production potential of livestock, and limited options for field crop and horticulture production in the lower areas.

Changes in migration are, however, only possible if alternative feed sources for the critical periods can be found. Fodder development activities in the temperate regions have had substantial impact on cattle migration. For Bumthang District, a 19% reduction in migration was already reported for 1983 (RNR-RC 1998).

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