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Improvement of Livestock Production in Crop–Animal Systems in Agro-ecological Zones of South Asia

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Foreword

From the livestock perspective, the South Asian region has many distinctive features. Of particular significance is the fact that more than half of the one billion poor people in the world are found in this region. The region has a large and diverse livestock population that accounts for 19% of the cattle, 60% of the buffalo, 30% of the goat and 7% of the sheep populations in the world. Livestock contribute in the order of 10% to 45% of the national agricultural gross domestic product (GDP) of countries of the region. A large proportion of the human population is dependent on livestock for food, security and survival.

With increasing urbanisation and demand for meat and milk, livestock provide opportunities for generating income for smallholder farmers, while meeting nutritional needs of both urban and rural families at affordable prices. Research can help ensure that these opportunities are met in socially, economically and environmentally sustainable ways.

A study was conducted to assess the constraints to production and research opportunities for enhancing the contribution of livestock in crop–animal systems in agro-ecological zones of South Asia. The study involved six countries: Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. This publication presents the results from this study.

The importance of livestock research is generally recognised. An aim of this study was to help set priorities and focus the limited resources in order that livestock research can be most effective.

The work was undertaken by a four-person team: Dr C. Devendra (ILRI) who was also the team leader, Dr D. Thomas (DFID), Dr M.A. Jabbar (ILRI) and Dr E. Zerbini (ILRI). Drs Devendra, Thomas and Jabbar visited all six countries, while Dr Zerbini visited India, Nepal, Pakistan and Sri Lanka. In each country, an expert nominated by the government undertook the assessment of animal health constraints. Their valuable contribution to this publication is acknowledged, as is the financial support for the study provided by the Department for International Development (DFID, formerly ODA), of the United Kingdom.

The assessment of research priorities for improved livestock production in South Asia in crop–animal systems complements an earlier study conducted in South-East Asia. Together, they provide valuable information on the potential role and contribution of livestock to sustainable agriculture in Asia.

Hank Fitzhugh
Director General
ILRI

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Executive summary

1. Agriculture in South Asia contributes 25–43% of the gross domestic product (GDP) of the region while livestock account for 10% to 45% of the agricultural GDP. About 57% of the human population depend on agriculture, including livestock, and about 40% of the people live below the poverty line.
2. Agriculture emphasises crop production, notably rice and wheat, based on high inputs and intensive systems. Irrigated agriculture has been developed in high potential areas, particularly in India, Pakistan and Sri Lanka, but most of the countries are still significantly dependent on rainfed agriculture.
3. A very large proportion of the people depend on livestock, which not only provide a means of security and survival, but also supply vital dietary animal proteins and cash income. The region has a large and diverse livestock population that accounts for 19% and 69%, respectively, of the world's cattle and buffalo numbers. Corresponding figures for goats and sheep are 30% and 7%, respectively. Nevertheless, current production and consumption levels of ruminant products are low. However, increasing populations, higher incomes, urbanisation and changing consumer preferences in the future will fuel increased demand for beef, milk, goat meat and mutton. Accordingly, productivity from ruminant livestock will need to be increased; most governments are giving priority to the development of this sub-sector.
4. Agriculture in the region is characterised by different production systems under both rainfed and irrigated conditions. Rice- and wheat-based systems are the most important, although a wide range of secondary annual and perennial crops are grown. Both monoculture and multiple cropping systems are common, with crops being grown for subsistence and cash. Animal production systems are classified mainly into extensive grassland-based systems and those combining livestock with arable cropping. Ruminants are found in both systems and non-ruminants mainly in the latter; the integration of aquaculture is important only in Bangladesh. Perennial tree crop systems are less important. Significant crop–animal interactions occur in the farming systems.
5. Major research and development opportunities exist to increase productivity from these systems, improve the livelihoods of poor rural people, ensure food security, and address concerns of gender, equity and environmental protection. To provide a sharper focus on the research priorities and programmes for livestock improvement in South Asia, the International Livestock Research Institute (ILRI) proposed a detailed assessment of the research and development needs to address the major constraints. This approach would also help establish linkages with the national agricultural research systems (NARS), and identify the opportunities for collaborative research to increase productivity in crop–animal systems. The assessment was undertaken in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka.
6. The results of the assessment of crop–animal systems are presented. Research to improve livestock production has been prioritised based on a detailed characterisation of the agro-ecological zones (AEZs), an extensive review of the literature, observations and discussions in the six countries, and the collation and analyses of results. The study has identified the major constraints, the research opportunities appropriate to ILRI, NARS and others, and organisational structures in national institutions and research capacity.

7. The AEZs have been re-classified, and priority given to the arid/semi-arid and subhumid/humid zones. Only relatively small parts of the region are characterised by humid conditions. Some 16 major soil groups, with different textural characteristics and fertility profiles, are found in all the AEZs.

8. A review of the literature indicated that there was a paucity of information on farming systems research that incorporates animals into cropping systems. Research on component technologies emphasising animal nutrition was very common, particularly the chemical treatment of crop residues. The methodologies for analysis of crop–animal systems are generally weak, and limited research has been conducted on post-production systems and socio-economics/policy. Diseases and feed resources are the most important constraints to animal production.

9. A wide range of feed resources are available that include native grasslands, improved forages, crop residues, agro-industrial by-products (AIBP) and various non-conventional feed resources (NCFR). Crop residues, mainly rice and wheat straw, are the most important feed resources in mixed farming systems, and AIBP and NCFR are largely under-utilised. Feed deficits are common and no attempt has been made to synchronise feed availability with animal requirements. Significant areas of native grasslands are found in the arid/semi-arid zones and in Alpine areas, and provide the major source of feed for ruminants in these regions. A wide range of improved grasses and herbaceous legumes have been evaluated for tropical and temperate conditions but, outside the irrigated systems, there is little use in farming practice. Studies with multi-purpose trees have emphasised the exotic species *Leucaena leucocephala* and *Gliricidia sepium*. However, in a number of countries, native tree fodder is used widely as feed at critical times of the year.

10. Overgrazing is a problem in the arid/semi-arid zones and in the Alpine grasslands. Pollution of surface water by manure occurs in peri-urban and urban production systems. Unregulated processing of animal products causes further pollution.

11. A wide range of diseases affect livestock and poultry. The diagnosis and monitoring systems for diseases are weak, and relatively little work has been conducted on the epidemiology of important diseases. Vaccine production is often inadequate to meet needs and vaccines are produced mostly without the use of modern biotechnologies. Veterinary delivery systems to farmers are generally weak.

12. Considerable biodiversity exists in breeds within given species in South Asia. However, characterisation of these indigenous breeds has been limited, and many are threatened by genetic erosion. Crossbreeding of indigenous cattle with exotic breeds for milk production is widespread and beneficial, but has also contributed to the relative neglect of indigenous livestock.

13. The conclusions drawn from the field visits in general concurs with existing literature from the region. The importance of crop–animal systems and the multiple roles played by livestock were confirmed in every country. Similar systems occur throughout the region but vary in relation to AEZ, feed type and availability, the intensity of mixed farming operations and the response to market opportunities. In cattle, crossbreeding with temperate breeds is widespread but uncontrolled. Buffalo are important for milk production, but limited attention has been given to their improvement through selection. Considerable genetic erosion of indigenous breeds has taken place with all species of livestock. The major animal diseases are the same in every country and rank with feed resources as the major technical constraint. Socio-economics/policy research has been neglected. Much of the research conducted by the NARS lack a farming systems perspective and disciplinary barriers exist in all institutions. Research capacity in the NARS varies from minimal to good, but priority-setting is weak in all cases. Opportunities exist for improved information exchange.

14. The literature review and country visits enabled key researchable issues to be identified through a situational analysis. The analyses re-emphasised that the major technical constraints to animal production were feed resources and animal health. Several researchable issues in socio-economics/policy were also identified, as were training and information needs.

15. Finally, two priority production systems were identified for future research: dairy production systems in rainfed and irrigated mixed farming systems, and small ruminant production systems linked with annual cropping in the rainfed mixed farming systems. Multi-disciplinary project development related to these two systems is described along with human resource requirements. Research partnerships between ILRI, NARS and other international centres/organisations will be essential for successful programme development.

1 Background

Introduction

The International Livestock Research Institute (ILRI) has a global mandate to provide leadership in research on animal agriculture for the Consultative Group on International Agricultural Research (CGIAR). The process used to define this global agenda involves developing appropriate research programmes to improve livestock in priority agro-ecological zones (AEZs). This task has been facilitated by regional consultations and the identification of requirements for livestock research in the different regions of Asia, Latin America and the Caribbean, and West Asia and North Africa (Gardiner and Devendra 1995). To provide a sharper focus on the research priorities leading to the development of research proposals, an assessment of trends in production and consumption of livestock products in selected countries in Asia and their implications for research in the region was completed by Vercoe et al (1997) with support from the Australian Centre for International Agricultural Research (ACIAR). An assessment of livestock production, related constraints and research needs in crop–animal systems in rainfed AEZs in South-East Asia was also completed with support from the Government of Japan and the Department for International Development (DFID) of the United Kingdom (Devendra et al 1997). This study focuses on livestock production systems, constraints to production, priorities for research, and opportunities for their improvement in South Asia.

The setting

Agriculture in the region

In 1996, South Asia had 1.2 billion people, representing 22% of the world population. The human population in the region has been projected to increase to 1.6–1.7 billion by the year 2010. In all of the countries, agriculture is a major activity contributing 25% to 43% to gross domestic product (GDP). Livestock contribute 10% to 45% to the agricultural GDP (Table 1), but this proportion is higher if the values of manure and draft power are included. About 57% of the population are dependent on agriculture including livestock. Total and per capita agricultural output increased annually by 3.1% and 0.7%, respectively, during 1970–90 and are projected to increase by 2.6% and 0.6%, respectively, during 1989/90–2010 (World Bank 1994; Alexandratos 1995).

In national agricultural policies crops, particularly rice and wheat production based on irrigation and high inputs, have been emphasised to meet the grain needs of the rapidly increasing population. Irrigated agriculture has been developed in high potential areas but, with the exception of Pakistan, the countries remain significantly dependent on rainfed agriculture. Some 12–93% of the people live in rainfed areas, and 26–84% of the arable land and 5–41% of agricultural output come from these areas. Due to low productivity, the shares of crop and livestock output coming from rainfed areas is much lower than the share of the total area under rainfed agriculture. It is estimated that 70–90% of the ruminant livestock are found in mixed farms in rainfed areas in the different countries in the region. Most of the future demand for milk and ruminant meat is expected to come from the improved productivity of animals in mixed farming systems. Improving the productivity of these systems will require removal of technical and socio-economic constraints through research and technology-transfer with appropriate policy support.

Table 1. *Human populations (1996) and selected economic indicators (1992–94 averages) for South Asia.*[1]

Indicators	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Human populations (millions)	120.0	945.0	21.0	140.0	18.0
Per capita income (US$)	220.0	300.0	190.0	430.0	600.0
Share of agricultural GDP (%)	30.0	31.0	43.0	25.0	25.0
Livestock share in agricultural GDP (%)	14.0	23.0	15.0	45.0	10.0
Calories available/per capita/day	2022.0	2397.0	2126.0	2400.0	2242.0
Protein available/per capita/day (g)	43.3	58.0	55.1	58.9	47.1
Protein from animal sources (%)	12.5	15.7	14.0	29.2	21.2
Consumption/per capita/annum (kg)					
Ruminant meat	2.1	3.3	na[2]	10.6	1.9
Non-ruminant meat	0.7	1.0	na	2.0	2.9
Total meat	2.8	4.3	8.2	12.6	4.8
Milk	18.5	69.4	46.0	136.3	30.3

1. Data for Bhutan were not available.
2. na = not available.
Sources: FAO (1996a; 1997).

In 1995, the region accounted for 19% of the world cattle population and 69% of the world buffalo population. Corresponding figures for goats and sheep were 30% and 7%, respectively. However, output shares were significantly smaller because yields are low. Milk yield per animal was about 43% of the world average and about the same as the developing world average; beef and veal yields were about 50% of the world average and 65% of the developing world average; and mutton and lamb yield were about the same as the developing world average (FAO 1997). The poultry population is projected to increase 1.5 times by 2010 and will meet much of the increased demand for meat (Table 2). The buffalo population will increase faster than the cattle population, and the goat population will increase faster than the sheep population. The growth in milk production is less certain, as it will depend largely on the success of dairy development programmes, crossbreeding and associated technological changes. In all countries, except Bangladesh and Bhutan, a major shift is taking place from cattle to buffalo milk production. The reasons for this include customer preferences for higher butterfat contents, consistency in milk yields under poor management conditions, longer productive life and higher value of buffalo.

Table 2. *Animal populations and meat and milk production in South Asia.*

	Populations ($\times10^6$)			1996 production ($\times10^3$ mt)	
Species	1996	2010	Change (%)	Meat	Milk
Buffalo	105.3	122.8	16.6	1848.0	47549.0
Cattle	247.4	278.2	12.4	1812.0	38764.0
Goats	202.6	273.1	34.8	1090.0	3941.0
Sheep	77.3	91.0	17.7	452.0	97.0
Pigs	12.7	14.8	16.6	435.0	-
Poultry	884.0	2332.0	163.8	1080.0	-

Sources: FAO (1996b; 1997).

Current production and consumption levels of meat and milk are rather low (Table 1). India is a small net exporter of meat; all the other countries are self-sufficient. During 1970–94, per capita meat consumption decreased in Bangladesh and Sri Lanka and increased in the other countries. In both Bangladesh and Sri Lanka, non-ruminant meat consumption increased marginally but the decline in the consumption of ruminant meat was higher resulting in negative growth rates in consumption. Currently, Bangladesh and Sri Lanka are deficient in milk in relation to effective demand by 11% and 48%, respectively. The other countries are self-sufficient.

Population growth, urbanisation and income growth will lead to rapidly-increasing demands for meat and milk. Vercoe et al (1997) projected that India and Pakistan will remain self-sufficient with respect to milk production and consumption in 2000 and 2010, and Bangladesh may also become self-sufficient by 2010. In all countries, the demand for meat (particularly ruminant meat) will outstrip supply by up to 50%. The World Bank (1996) projected that, by 2010 in India, demand for milk will increase by a factor of about 10, eggs by a factor of 7 and mutton by a factor of 8. If the 1980–92 growth rates (3.3–6.5% for poultry, beef and mutton) are maintained up to 2010, the demand for these products may well be met. However, at current growth rates, only 50% of the demand for milk will be met by 2010.

Level of poverty

More than half of the one billion poor in the world live in the region. The number of poor people increased from 532 million in 1985 to 562 million in 1990, but this has been projected to decrease to 511 million by 2000. However, the proportion of poor people decreased only marginally from 52% in 1985 to 49% in 1990 and has been projected to decrease to 37% by 2000. About 49% of the population live below the poverty line (World Bank 1993). Equally alarming is the very high percentage of rural poor as a percentage of the total poor which, for India, is about 79%. The Poverty Gap Index (defined as the distance of the average income of the poor living below the poverty line expressed as a percentage of the poverty line) decreased from 16.2% in 1985 to 13.7% in 1990, and is expected to decrease further over time. The number of undernourished people is projected to decrease from 265 million in 1990 to 203 million in 2010 (World Bank 1994; Alexandratos 1995). The alleviation of poverty in the region remains a major task because the per capita income and availability of food are very low (Table 1), and a large number of people are still vulnerable to poverty and malnutrition.

The poverty dimension involving the rural poor concerns mainly small farmers, the landless, transhumant and nomadic pastoralists, women, tribal groups and displaced persons. A very large proportion of these individuals is associated with livestock, which not only provide a means of survival and security, but also supply vital dietary animal proteins and cash income. For example, in India, about 75% of rural households are small and marginal farmers, who own 56% of the large ruminants and 62% of the small ruminants (World Bank 1996). Similar trends are observed in the other countries. These vulnerable groups merit special attention, and the role and contribution of livestock is an important means of achieving this objective. Livestock development links poor producers with urban consumers, thereby increasing income and employment in the rural areas.

Objectives of the assessment

General objective

The general objective is to characterise the role of animals and identify priority research areas to enhance their contribution to environmentally sustainable production systems for the improved welfare of rural families in rainfed and irrigated areas of South Asia.

Specific objectives

The specific objectives of the assessment were to:

- document the contribution of animals to the smallholder rainfed and irrigated farming systems in South Asia
- identify research priorities, opportunities and disciplinary needs for improved ruminant production systems in the region
- identify representative examples of the crop–animal production systems in rainfed and irrigated areas suitable for livestock research, through the assessment of existing research sites of national and international organisations in six countries in the region
- identify government agencies, private sector institutions and non-governmental organisations (NGOs), and key potential partner institutions and individuals working in this subject area
- assess existing research capacity and the comparative advantage for collaborative international and national livestock research in the region.

The study process

This study presents the results of the assessment of crop–animal systems in the AEZs of South Asia and the prioritisation of research to improve livestock production. It is based on an extensive review of the literature; observations and discussions with scientists, extension workers, policy makers and farmers in six countries in the region; and the collation and analysis of the results. The study has identified the major constraints to production; the research interventions appropriate to ILRI, the national agricultural research systems (NARS) and others; and the organisational structures and research capacity in national institutions. Together, the results enhance understanding of the research and resource requirements for programme development in South Asia.

The study involved six countries, namely Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. These countries represent the variability that exists in the crop–animal systems in the region. The work was undertaken in two phases over the period November 1997 to March 1998. Phase one involved characterisation of the AEZs and an exhaustive literature review on crop–animal systems, which was conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India. Phase two documented the contribution of animals to these systems based on visits to national programmes and field sites in the six countries, and a critical review of additional information. The visits also enabled identification of key institutions and individuals associated with different aspects of livestock research and an assessment of research capacity.

Study output

The results of the study are presented in the following six chapters. Chapter 2 gives a detailed characterisation of the AEZ; Chapter 3 characterises the farming systems and reviews the literature; Chapter 4 provides a field assessment of crop–animal systems; and Chapter 5 identifies the key researchable issues in crop–animal systems. In Chapter 6, the strategy for research is discussed and the final recommendations are presented. Finally, the bibliography provides a consolidated list of references. Appendix I provides detailed information on each of the six countries and Appendices II and III list the itinerary and persons met, respectively.

2 Characterisation and importance of agro-ecological zones in South Asia

Introduction

In an earlier assessment of the role of livestock in mixed farming systems in the AEZs of South-East Asia, the report dealt exclusively with rainfed agriculture (Devendra et al 1997). In this evaluation, although priority is given to rainfed AEZs, some discussion of irrigated systems relevant for livestock, particularly in countries such as Bangladesh, India, Pakistan and Sri Lanka, is included.

In Asia and the Pacific, the area under rainfed agriculture amounts to 223 million hectares, which represents some 67% of the total arable land (ADB 1989). Within this rainfed area, approximately 52% of the land is found in the six countries of South Asia, amounting to some 116 million hectares (Table 3). The proportion of arable land under rainfed agriculture varies from 26.7% for Pakistan to 84% for Nepal. Only in Pakistan (73.3%) and Sri Lanka (50.6%) does the proportion of irrigated land exceed that in the rainfed areas. However, in absolute terms, the largest amount of irrigated land, 43.8 million hectares, is located in India.

Table 3. *Importance of rainfed agriculture in South Asia.*

Country	Total rainfed area ($\times 10^6$ ha)	Rainfed area as proportion of total arable land (%)	Rainfed production as proportion of agricultural GDP (%)	Population dependent on rainfed agriculture (%)
Bangladesh	7.70	81.6	40.5	41.0
Bhutan	0.07	81.0	28.9	93.0
India	100.00	69.5	25.7	42.2
Nepal	2.63	84.0	40.9	74.8
Pakistan	5.43	26.7	4.6	11.5
Sri Lanka	0.53	49.4	20.1	29.1

Source: ADB (1989).

Rainfed production accounts for 4.6–40.9% of agricultural GDP. From 11.5% to 93.0% of the human population in the six countries depend on rainfed agriculture for its livelihood. Most of the resource-poor farmers engaged in rainfed agriculture are smallholders with farm sizes averaging 1.5 ha. Alexandratos (1995) estimated that rainfed land suitable for cropping in South Asia, and currently not utilised, approximates 37 million hectares. The potential for the production of crop residues and agro-industrial by-products (AIBP), for use as animal feeds, would be enormous if only a fraction of this land was cultivated.

Characterisation of the agro-ecological zones

Definition of AEZs

For consistency with definitions used by the CGIAR, the classification of AEZs has been adopted from the Technical Advisory Committee (TAC) of the CGIAR (TAC 1994). In this system, the original AEZ 1 (warm arid and semi-arid tropics) and AEZ 5 (warm arid and semi-arid tropics with summer rainfall) are consolidated to cover the arid/semi-arid zones; AEZ 2 (warm subhumid tropics) and AEZ 6 (warm/cool subhumid subtropics with summer rainfall) are combined to cover the subhumid zones; AEZ 3 (warm humid tropics) and AEZ 7 (warm/cool humid subtropics with summer rainfall) are aggregated to cover the humid zones; and AEZ 4 (cool tropics) and AEZ 8 (cool subtropics with summer rainfall) are consolidated to cover the cool tropical zones with summer rainfall (Fischer 1995). A fifth zone encompasses the cool subtropics with winter rainfall. In this study, priority is given to the first three AEZs. The cool tropics/subtropics with winter/summer rainfall predominate outside the South Asia subregion, in China and adjoining border areas and in West Asia. Small areas that may occur in South Asia are in the northern Himalayan region and are more associated with Alpine grassland-based systems.

Humid AEZs are characterised by a length of growing period (LGP) in excess of 270 days; subhumid AEZs have a LGP ranging from 180 to 270 days; and arid/semi-arid zones have LGPs varying from 0 to 74 days (arid) and 75–179 days (semi-arid). South Asia is dominated by climates that range from arid to subhumid. Only Bangladesh, small parts of north-west, eastern and southern India and south-west Sri Lanka are characterised by humid conditions. India has by far the largest human population living in the semi-arid tropics; more than 400 million people or 55% of the total for the semi-arid tropics globally. Total rainfall in South Asia ranges from less than 75 mm in western India, the northern Himalayan regions of Bhutan and Nepal and parts of Pakistan to over 3000 mm in Bangladesh and Sri Lanka. Rainfall varies from year to year and is erratic and unreliable in the drier zones. In the wet season in these drier areas, dry spells can occur which may result in the complete loss of a crop. In Bangladesh, some 93% of arable land is found in regions with a 4–5 month wet season. In Nepal and Sri Lanka comparable values are 88% and 63%, respectively. However, in India, only 26% of arable land is found in zones with a 3–4 months wet season. The extent of the major AEZs in South Asia is shown in Figure 1. A classification of farming systems in which livestock occur is given by Sére et al (1995) for the major AEZs.

Soils

The soil classification systems suffer from considerable confusion and a lack of consistency between countries. Therefore, presenting a standardised classification is not easy. There are 16 major soil groups in South Asia with different textural characteristics and fertility profiles. The four largest soil groups are the Lithosols, Luvisols, Cambisols and Vertisols in that order. The Yermosols, Arenosols, Acrisols, Nitosols, Fluvisols and Xerosols follow these again in order of importance. The remaining soil groups occupy relatively small areas of land regionally. The three major soil groups, in descending order of area covered, are given in Table 4.

Table 4. *The most important soil groups in the six countries of South Asia.*

Bangladesh	Bhutan	India	Nepal	Pakistan	Sri Lanka
Gleysols	Acrisols	Luvisols	Cambisols	Lithosols	Luvisols
Cambisols	Lithosols	Vertisols	Lithosols	Yermosols	Acrisols
Fluvisols	Cambisols	Cambisols	Fluvisols	Arenosols	Fluvisols

In Bangladesh, 78.5% of arable land is under Gleysols; in India, 27.4% of arable land is under Luvisols and 22.4% under Vertisols; and in Sri Lanka, 69% of arable land is under Luvisols and 25.6% under Acrisols (ADB 1989).

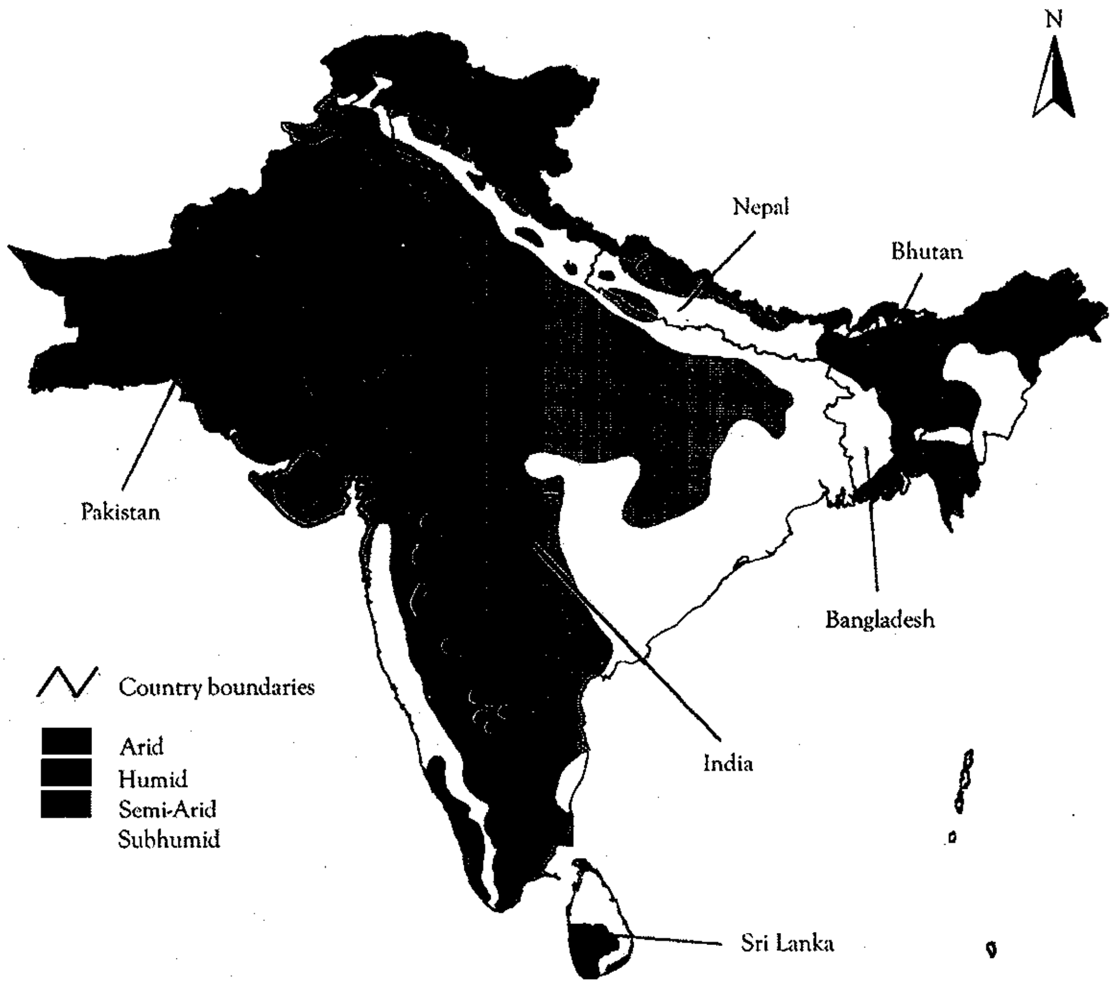

Figure 1. *Agro-ecological zones of South Asia.*

Rainfed farming systems

Background information for Asia on the priority AEZs is presented in Table 5. Currently, data limited to the AEZs in South Asia are not available, so the statistics shown include South-East Asia. However, most of the arid/semi-arid lands and a significant proportion of the subhumid zone occur in South Asia. The humid areas of South Asia are relatively small, and occur mostly in Bangladesh, parts of India and Sri Lanka. The largest areas of both rainfed and irrigated arable land occur in the arid/semi-arid zones. These zones, together with the subhumid zone, produce nearly 50% of the food crops and some 60% of the cash crops grown in Asia.

Mixed farming systems that include crops and animals are found in all the AEZs. Major crops include rice, wheat, maize, sorghum, pearl millet, pulses, oilseeds, sugar-cane, jute and cotton. Ruminants (cattle, buffalo, sheep and goats) and non-ruminants (pigs and poultry) are integrated into both rainfed and irrigated systems. In the cool tropics/subtropics, which is not a priority zone in this study, species such as yak (*Poephagus gruniens*) and mithun (*Bos frontalis*) are found. However, these animals are associated predominantly with Alpine grassland-based systems.

Table 5. *Human populations, food demand and land use in the priority AEZs of Asia.*

Parameters	Arid/semi-arid zones		Subhumid zone		Humid zone		
	Amount/ number	% of Asia	Amount/ number	% of Asia	Amount/ number	% of Asia	% of Asia[2] in AEZ
Human populations in 2010 ($\times 10^6$)	1311.4	35.7	588.8	16.0	1264.5	34.4	86.1
Food demand in 2020 ($\times 10^6$ t GE)[1]	358.6	33.4	175.5	16.3	383.9	35.8	85.5
Production of food crops ($\times 10^6$ t GE)	230.9	31.5	123.6	16.9	262.7	35.9	84.3
Production of cash crops ($\times 10^6$ t GE)	79.6	33.6	62.8	26.5	89.7	37.9	98.0
Land area ($\times 10^6$ ha)	327.6	16.1	237.7	11.7	534.1	26.2	54.0
Arable land ($\times 10^6$ ha)	191.9	41.5	73.0	15.8	123.4	26.7	84.0
Rainfed arable land ($\times 10^6$ ha)	126.8	38.8	55.2	16.9	86.1	26.3	82.0
Irrigated arable land ($\times 10^6$ ha)	65.2	48.0	17.8	13.1	37.3	27.5	88.6

1. TGE = tonnes of grain equivalent.
2. Excludes cool tropics.

Source: TAC (1992).

Conclusions

This chapter classifies the AEZs in South Asia. The priority AEZs are the arid/semi-arid, and subhumid/humid zones.

3 Characterisation of farming systems and review of research

Introduction

To assess and understand the farming systems in South Asia, an exhaustive review of available published and unpublished information was undertaken. This included scientific papers in international journals, proceedings of national, regional and international conferences, project reports, and miscellaneous publications from research and development organisations. The task was completed by a data search using online public access catalogues. A total of 3340 papers were reviewed, but only major references have been included in this report. The literature search was completed at ICRISAT and, to obtain first-hand knowledge of the six countries of South Asia, visits were undertaken to help assess developments.

Cropping systems and rangeland resources

Cropping systems

The main rainfed cropping systems in Asia have been described by Devendra et al (1997). These include systems based on the major food crops, perennial tree crops, and a wide range of secondary annual and perennial crops. Both monoculture (e.g. sorghum in India) and multiple cropping systems (inter-cropping, relay cropping, sequential-cropping) are common, with crops grown for subsistence and cash. Single Lowland Rice Crop Systems are found in most countries of South Asia (except Pakistan), and are particularly important in Bangladesh. Single Upland Crop Systems are the major systems in India, Nepal, Pakistan and Sri Lanka. Substantial areas of Multiple Rice Crop Systems are found in Bangladesh and India, whilst Multiple Upland Annual Crop Systems are of significance in India and Pakistan. Only in Bangladesh is aquaculture integrated with rice-based systems, particularly deepwater rice. Perennial Tree Crop Systems are less important than in South-East Asia, with the notable exceptions of southern India and Sri Lanka. Shifting cultivation is not a major system in South Asia, although it is practised in very small areas of Bangladesh, Bhutan, India, Nepal and Sri Lanka.

Hoque (1984) reviewed traditional cropping systems in both South-East and South Asia; a review of the major crops is given by ADB (1989). These are presented for South Asia in Table 6. In rainfed wetland areas, single and double cropping of rice is predominant. After a rainfed rice crop, wheat, maize, barley, millet, pulses and oilseeds may be grown with residual soil moisture. In other cases jute, maize and mung bean are also grown during the early part of the wet season before the rice is transplanted. In some areas intensive multiple cropping with three- or four-crop patterns is also practised. Inter-cropping and relay cropping are commonly used particularly in the dry season. In rainfed dryland areas the growing of drought-resistant, short-duration cultivars has been an important feature of crop production. There is extensive use of mixed cropping, relay cropping and inter-cropping of annual species. Cropping patterns may include up to six crops, with upland rice and maize as the most important commodities.

In irrigated wetland areas farmers use single, double or triple cropping patterns. The rice–rice sequence is important over a vast area. Triple rice cropping patterns are possible because of the availability of improved short-duration varieties. Where low temperatures are a limiting factor during the dry winter season (as in Bangladesh and Nepal) wheat, mustard and potato are grown after one or two rice crops. In irrigated dryland areas the wet season crop is often direct-seeded rice. However, in some patterns in the wet season maize, jute, sugar-cane, cotton and mung bean may also be grown. During the dry season wheat, potato, mustard, chilli and vegetables are grown under irrigation. Double cropping is a common practice. In some cases cropping intensity is increased through inter-cropping. In Bangladesh potato, chick-pea and wheat may be inter-cropped with sugar-cane during its early growth stage.

Table 6. *Important crops and cropping patterns in farming systems in South Asia.*

		Cropping patterns	
Country	Important crops	Rainfed	Irrigated
Bangladesh	Rice, wheat, pulses, oil-seeds, jute, sugar-cane	Rice–wheat Rice–rice–barley + chick-pea Upland rice–barley Upland rice–barley + chick-pea+linseed	Rice–rice Rice–rice–wheat Jute–mustard Sugar-cane–wheat
Bhutan	Maize, rice, wheat, barley, buckwheat, pulses, potato	Maize–oilseed Rice–wheat Rice–rice Rice–maize	Rice
India	Rice, wheat, sorghum, maize, pearl millet, pulses, oilseeds, cotton, sugar-cane	Rice–wheat Rice–chick-pea Rice–lentil Rice–mustard	Rice–wheat Sugar-cane Rice–rapeseed/ mustard
Nepal	Rice, maize, wheat, finger millet, oilseeds, potato	Rice–wheat Rice–finger millet Rice–wheat–fallow Maize/finger millet–wheat	Rice–rice Rice–potato Rice–rice–wheat Maize–rice–wheat
Pakistan	Wheat, rice, maize, sorghum, millet, barley, chick-pea, rapeseed, cotton, sugar-cane	Rice–potato Sorghum–wheat + mustard Groundnut– wheat Maize + beans–potato	Rice–wheat Maize–wheat Cotton–wheat Rice–chick-pea
Sri Lanka	Rice, maize, pulses, oilseeds, cassava, chilli	Rice–onions Rice–rice Maize–onions Rice–potato	Rice–rice

Sources: Hoque (1984); ADB (1989); Anon (1995); Reynolds et al (1995).

In deepwater rice areas in Bangladesh single, double or triple cropping patterns are practised. Crops associated with these areas include rice, mustard, potato, jute, wheat, millet, chick-pea, grasspea, sesame, water-melon, tobacco, onion and chilli. In the tidal swamp areas of Bangladesh, major cropping patterns include rice, jute, sugar-cane, lentil, sesame, coconut and betelnut.

Rangeland resources

In South Asia, rangelands containing mainly native grasses and shrubs are an important feed resource for ruminants, particularly in India and Pakistan (UN 1994). Most of the rangelands are located in the arid/semi-arid zones and contain sparse vegetation (<1 t/ha dry matter) and support low carrying capacities (e.g. 5–10 sheep/ha in Balochistan Province, Pakistan). Yields of dry matter in the better native pastures of the Himalayas and sub-humid zone can be of the order of 3–4.5 t/ha. In addition to the rangelands, ruminants graze native pastures on roadsides, on paddy bunds, in fallows and in forests.

In Bhutan about 9% of the total area is grassland, and these areas are found mainly in the northern parts of the country. Native grasses under forests are a major source of feed for livestock and together with open grasslands provide about 45% of the fodder requirement. Trees account for 15% of the fodder requirement. Grassland vegetation is very diverse due to climatic factors. Shrubs, trees, broadleaf weeds and grasses of poor grazing potential are found in the humid tropical southern part of the country. From 800 to 2000 m altitude, in the arid subtropical/lower temperate belt, the principal grasses are those of the genera *Bothriochloa, Chrysopogon, Cynodon, Panicum* and *Paspalum*. These grasses are suitable for grazing only in the early growth stages. *Themeda–Arundiniacae* associations are found on the drier slopes of the upper temperate zone between 2500 and 2800 m altitude. Bamboo, associated with species of *Agropyron* and *Fescue*, is found on slopes between 2500 and 3500 m, but has little value except as a winter feed for yak. Alpine and sub-Alpine pastures are found in the northern part of Bhutan between 3500 and 5000 m altitude. These pastures are used for summer grazing by yak and sheep from the end of June to mid-September.

Rangelands in India cover about 40% of the country and supply about 33% of the total feed intake by ruminants. Grasslands are taken to include rangelands, forest grazing, wastelands and fallows. Five major associations are distinguished (Sastry 1995). Tropical *Sehima–Dicanthium* associations are found over tropical peninsular India in the arid/semi-arid zones and in coastal regions. In the subtropical arid/semi-arid regions of Gujarat, Rajasthan, Uttar Pradesh and Punjab *Dicanthium–Cenchrus–Lasiurus* associations are found. Throughout the northern Gangetic Plain *Phragmites–Saccharum–Imperata* associations are dominant. In the humid northern and north-west montane regions and the moist sub-humid regions of Assam, Manipur, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh and Jammu and Kashmir, *Themeda–Arundinella* associations predominate. In the high altitude western and eastern Himalayas, temperate Alpine pastures occur. Grazing intensity is high in the tropics and low in the mid-Himalayan region. In the high altitude Himalayan rangelands grazing is seasonal and based on transhumance.

Grasslands in Nepal occur over 37% of the country, primarily in the northern mountains. Three categories of rangeland types have been identified, viz. Mountain pastures (>1800 m), Hill pastures (500–1800 m) and Tarai pastures (<500 m). Mountain pastures consist of Alpine meadows, steppe and forest grazing areas. Alpine pastures have a short growing season and are grazed from June to October. The predominant genera are *Agropyron, Agrostis, Bromus, Chrysopogon, Cymbopogon, Dicanthium* and *Poa. Eragrostis, Heteropogon, Chrysopogon, Digitaria, Imperata* and *Bothriocloa* dominate hill pastures. Hill pastures are used heavily, and overgrazing and erosion have occurred in these areas. Migration of livestock in winter from Alpine pastures accentuates the problem. In the crop-dominated Tarai, limited grazing is allowed on fallow land and animals spend most of their time in forest grazing. The main genera are *Paspalum, Digitaria, Cynodon, Heteropogon* and *Imperata*.

Some 65% of the total area of Pakistan, from altitudes of 0 – >4000 m, are rangelands. Their extent varies from 47% in Punjab Province to 93% in Balochistan Province. Rangelands meet 60% of total feed requirements of small ruminants and 5% of the requirements of large ruminants. Only 4.8% of Pakistan is under forest. Six major rangeland types are to be found in Pakistan. Alpine pastures are found above 3000 m altitude, and consist of slow-growing perennial, herbaceous and shrubby vascular plants and extensive mats of mosses and lichens. These pastures are grazed by nomadic livestock primarily small ruminants. Trans-Himalayan pastures extend from below 2300 m to over 3300 m. These grasslands are heavily grazed, especially in winter, when animals are unable to graze Alpine pastures. Himalayan forest pastures are found in moist temperate and subtropical subhumid/humid zones where forests of species such as spruce and fir occur. Major genera include

Acacia, Olea, Dodonaea and *Imperata*. The Pothowar scrub grasslands lie between 300 and 1500 m altitude in the subtropical semi-arid/subhumid zones. Important genera in these grasslands include *Acacia, Olea, Dodonaea, Heteropogon, Aristida* and *Eleusine*. Desert rangelands occur in the Thal, Cholistan and Thar regions. Vegetation in these rangelands includes the genera *Pennisetum, Aristida, Acacia, Eleusine, Cymbopogon, Lasiurus* and *Cenchrus*. Most of these rangelands have been degraded. The Mediterranean rangelands of Balochistan province are characterised by genera such as *Prosopis, Zizyphus, Cenchrus, Eleusine, Pennisetum, Aristida* and *Chrysopogon*. The central areas receive rains (100–400 mm) during winter or early spring and the western areas (50–200 mm) summer rains. In the eastern areas the grasslands receive both winter and summer rainfall, but due to heavy grazing pressures the areas are infested with unpalatable species.

Sri Lanka has only about 0.5 million hectares of native grasslands containing genera such as *Panicum, Pennisetum, Cynodon, Axonopus* and *Eragrostis*. Nevertheless, these areas contribute >90% to total pasture production. Montane grasslands are under heavy grazing pressures with genera such as *Brachiaria, Chrysopogon, Cymbopogon* and *Themeda* predominating.

Animal genetic resources

Indigenous breeds

Animal genetic resources in South Asia are unique in several features. First, they reflect the considerable population size and diversity in breeds that exist within given species. These breeds constitute a high proportion of the total number of breeds in the whole of Asia. Buffalo, cattle, goats and sheep account for 74.0%, 61.6%, 56.0% and 22.8% of the total populations in Asia, respectively. In addition, South Asia has about 19% and 37%, respectively, of the world total of cattle and small ruminant breeds. Second, the indigenous breeds are distributed widely across all of the AEZs from the arid/semi-arid areas of India and Pakistan, through the high altitude Himalayan region, to the humid zones of Bangladesh, southern India and Sri Lanka. Third, many of these breeds, particularly small ruminants, are associated very closely with poor people for whom they provide security and an opportunity to improve their livelihoods. In the semi-arid zone, where they provide the main means of survival, goats and sheep provide between 27% and 100% of total farm income (Devendra 1996).

Despite the importance and potential value of these breeds, many of them have been neglected. In all countries, several breeds are referred to as 'nondescript' implying that they have not been described or characterised adequately in terms of important traits and potential productivity. There is a need to study fully these indigenous genetic resources in every country, so that they can make a more valuable contribution in the environments to which they are adapted.

Important cattle breeds in South Asia include the Sahiwal, Gir, Tharparkar, Kankrej, Dhanni, Ongole (Nellore), Häriana and Red Sindhi; those of buffalo include the Jaffarabadi, Surti, Murrah and Nili–Ravi; those of sheep the Chokla, Ganjam, Magra, Muzzafarnagri and Nellore; and those of goats the Barbari, Beetal, Black Bengal, Jamnapari and Sirohi. Valuable indigenous germplasm also exists for the yak, the mithun, the camel (e.g. the Malvi of Madhya Pradesh, India) and poultry (e.g. the Aseel fowl of northern India).

Crossbreeding

Crossbreeding of indigenous stock with exotic animals is acknowledged widely to be a valuable strategy for rapidly increasing production through the exploitation of hybrid vigour. Perhaps the best example of crossbreeding in South Asia is the use of temperate cattle to improve milk production.

Spectacular increases in production have been registered in countries such as India through the National Dairy Development Board (NDDB), and first generation crossbreds generally have yields that are twice those of the indigenous pure-breds (Matthewman 1993; Samdup 1997). However, there is a down-side to crossbreeding. Such programmes are often difficult to sustain, and there are problems in developing practical policy guidelines to ensure consistant approach. The priority given to crossbreeding is one of the reasons for the incomplete characterisation of indigenous breeds. Often, short-term productivity gains from crossbreds are considered to be more important than the rational use of indigenous breeds and the maximisation of their production through selection. Furthermore, vested interests in developed countries (often through aid programmes) have done a disservice to many of these countries by exporting breeds for genetic improvement that are inappropriate for smallholder management conditions and lack adaptation to the prevailing environmental conditions. Some of the problems associated with crossbreeding programmes in South Asia can be summarised as follows:

- Crossbreeding programmes have lacked co-ordination, and have been constrained by problems of infertility and instability in the crossbreds, difficulties with artificial insemination on farm and the poor availability of high quality breeding stock.
- The level of exotic blood in crossbreds is highly variable on farm and ranges from about 25% to 75%, despite a general agreement that first generation crosses represent the optimum. In most countries farmers are even demanding pure-bred stock when their management skills are clearly inadequate.
- The productivity levels achieved on experimental stations are seldom achieved on farm because of poorer nutrition, hygiene and management. Often, animal health problems (e.g. tick-borne diseases) that were not evident with indigenous breeds become important as crossbreeding programmes evolve.
- Perhaps the most damaging effect of the widespread development of crossbreeding programmes is the genetic erosion of valuable indigenous breeds and the threat of ultimate extinction. This was well-illustrated recently for India in a review by Khurana (1997). Endangered breeds include the yak in Ladhakh and the north-east states, the mithun also in the north-east states, the Bhadawari buffalo, the Hariana cattle of Haryana, the Vechur cattle of Kerala, the Chegu goat of Himachal Pradesh, and the Aseel fowl of northern India. An ironic situation has arisen where India is now importing its indigenous genetic material from other countries. Furthermore, valuable genes from indigenous Vechur cattle and the 'Booroola' gene in sheep have been patented in other countries. In Pakistan, the number of Sahiwal cattle in Punjab Province, originally thought to be 100,000, has fallen to below 6000 in 12 out of 16 districts. In Bhutan, only 191 pure-bred mithun exist compared with 65,000 mithun/cattle crossbreds.

Animal production systems

The main ruminant production systems in Asia have been described by Devendra et al (1997). In South Asia, because of the larger areas of rangeland, extensive grazing systems are more important than in South-East Asia. The types of rangeland found in the region have already been described. Nomadic and transhumant systems, which involve vertical or horizontal migration, are common in the arid/semi-arid regions of India and Pakistan and in the cool tropics of the Himalayas. In these systems cattle and small ruminants graze over long distances and migrations may last as long as 5–6 months. For example, in Azad Kashmir in Pakistan migrant Bakharwal tribesmen travel seasonally between the upper reaches of the Neelum valley and the Rawalpindi Division (Ishaque 1993). They reach the Alpine pastures by the end of spring, graze during the summer, and return to the Jhelum District in winter. This involves travelling 150 km in 7 days. An important aspect of many of these migrations is that small ruminants may be penned overnight in the fields to deposit manure and urine on arable land. This service may be paid for in cash or in kind (crop residues for feed). Environmental problems associated with these extensive grazing systems will be described later in this chapter.

In the annual crop–livestock systems, animals use native pastures (roadside verges and fallows), crop residues and AIBP. Animals are stall-fed, allowed to graze freely or tethered. Outside of the irrigated areas in countries such as India and Pakistan, there is little integration of improved forages with cropping. Systems integrating perennial tree crops with livestock are less important than in South-East Asia. Perhaps the best example of such systems is the coconut plantations in Sri Lanka and South India where both large and small ruminants graze unimproved pastures. However, opportunities for integration also exist in the coconut areas of southern India and under fruit trees in many of the countries.

Crop–animal interactions

The integration of crop and animal production is well developed in the farming systems of South Asia, particularly those in smallholder agriculture. The main types of interactions are presented in Table 7, and some examples from the countries visited are given in Table 8. In some cases, the type of interaction may change due to a shift in some component of the system. For example, where irrigation and mechanisation are spreading, crop–livestock interactions are declining compared with the rainfed areas (Byerlee and Husain 1993).

Table 7. *Main crop–animal interactions in mixed farming systems.*

Crop production	Animal production
Crops provide a range of residues and AIBP that can be used by ruminants and non-ruminants.	Large ruminants provide draft power for land preparation and for soil conservation practices.
Improved forages can be introduced into annual and perennial cropping systems to provide feed for ruminants.	Both ruminants and non-ruminants provide manure to maintain and improve soil fertility. In many farming systems manure is the only source of nutrients for cropping.
Agroforestry systems such as alley cropping can provide forage for ruminants.	The sale of animals and animal products and the hiring out of draft animals can provide cash for buying inputs such as fertiliser and pesticides used in crop production.
	Animals grazing vegetation under tree crops can control weeds and help to increase yields of the plantation crops.
	Animals provide entry points for the introduction of improved forages into cropping systems. Herbaceous forages can be undersown in annual and perennial crops and shrubs or trees established as hedgerows in agroforestry-based cropping systems.

Animal traction

Smallholder farming systems in South Asia have a long history of using draft animal power. In Bangladesh, some 80–85% of land preparation is carried out with large ruminants despite an increasing interest in mechanisation. In Bhutan, cattle, mithun and yak are used for draft purposes. In India, cattle, buffalo, equines, camels and yak are important for draft power in the different AEZs. The production of draft bullocks is still an important aspect of cattle rearing in India (Singh 1995), and it is estimated that there are some 70 million working animals in this country. The number of working bovines per hectare of net sown land in India is about 0.6 (Vaidyanathan 1988). In Nepal, almost all crop cultivation involves animal power (Shrestha and Pradhan 1995). In addition to cattle, buffalo and yak, Baruwal sheep and Sinahal goats are used in Nepal for haulage in the mountain regions, and can carry weights of 10–20 kg depending on body size. In Pakistan, cattle are the main draft animals. In Sri Lanka, both cattle and buffalo are used, with 90% of the swamp buffalo providing draft power, predominantly for land cultivation in rice. These observations underline the enormous contribution of animals, particularly large ruminants, to draft power. However, the situation has often been taken for granted and, with the exception of limited studies in India, very little research on draft power has been undertaken in South Asia. The use of mechanical power is increasing but, given the importance of traditional agriculture in the region, increased resources to improve the contribution of large ruminants to draft power are required.

Table 8. *Some examples of crop–animal interactions in South Asia.*

Country	Interactions
Bangladesh	Use of cattle and buffalo for draft power in rice production throughout the country
	Use of rice straw by cattle and buffalo throughout the country
	Use of manure from large ruminants for rice production throughout the country
Bhutan	Use of rice straw by cattle in the western lowlands
	Use of manure from cattle for cropping throughout the country
	Use of cattle for draft power in the lowlands
India	Use of manure from small ruminant flocks folded on arable land in Gujarat and Rajasthan states
	Use of sorghum residues by cattle in Andhra Pradesh State.
	Use of cattle for draft power in rice–wheat production systems on the Gangetic plains
Nepal	Use of manure from cattle and buffalo for composting in the Mid-Hills region
	Use of crop residues by cattle in the Tarai region
	Use of cattle and buffalo for draft power in the Tarai and Mid-Hills regions
Pakistan	Introduction of improved forages in irrigated cropping systems in Sindh and Punjab provinces
	Use of crop residues by buffalo and cattle in the Barani areas of Sindh and Punjab provinces
	Use of manure from large ruminants for cropping in Sindh and Punjab provinces
Sri Lanka	Use of buffalo to prepare land for rice production in the wet and intermediate zones
	Utilisation of rice straw by cattle in the irrigated dry zone
	Use of cattle for weed control and manure for coconut in the intermediate zone

Animal feeds from crops

Crop production provides a wide range of residues and AIBP that can be fed to ruminants and non-ruminants (Singh et al 1995b). References to feed availability in South Asia can be found in Renard (1997). In Bangladesh, crop residues contribute 70% of the feed requirements of animals and are derived mainly from rice, wheat and pulses; rice straw and bran contribute 90% of the energy available for ruminants. However, only 40% of the straw produced is used for livestock feed, due to alternative uses and losses in storage. In Bhutan, particularly in the more lowland areas of the west and north where crops are cultivated, cereal residues are available for livestock. However, the extent of their availability and use is not well defined. In India, the principal crop residues are the straws of cereals (rice, wheat, sorghum, maize and pearl millet) and pulses. The type and quality of these residues vary according to the AEZ where the crops are grown and the cropping patterns. In the irrigated areas of the country small farmers mix cereal straws with green forage for animal feed. Singh et al (1997) report that some 350 million tonnes of crop residues are available in India, constituting 66% of the required feed supply. However, this estimate probably assumes that all of the crop residues produced are available for livestock feed when, in practice, they are not. In Nepal, cereal straws contribute 51% of the total available feed resources. This value approximates their contribution to the energy and protein requirements of ruminants. The contribution of crop residues decreases from 67% in the Tarai to 6% in the high mountain areas (NARC 1996). In Pakistan, some 40 million tonnes of crop residues are produced annually and crop residues contribute 46% of the feed resources. These figures are likely to increase given the high priority for cereal production (Renard 1997). Wheat and rice are the most important crop residues and they contribute 52.5% and 22%, respectively, to animal feed requirements. In the major crop-growing provinces of Punjab and Sindh, crop residues contribute 54% and 45% of the energy and protein supply, respectively, to the diets of large ruminants (Pasha 1997). The major crop residue in Sri Lanka is rice straw, and about 50% is used as animal feed (Perera 1992). Much research has been conducted in the region on the improvement of cereal straws, through biological and chemical treatments, and the references in the literature to this technology are legion.

Although AIBP and non-conventional feed resources (NCFR) contribute <10% to ruminant feed, a considerable amount of research has been undertaken with AIBP, NCFR (Punj 1988) and the protein supplementation of low quality roughage (Girdhar et al 1991; Rai et al 1995). AIBP include oilseed meals, cereal brans (principally rice and wheat), cereal grains and brewers grains. NCFR include wastes from the fruit canning industry, abattoir wastes, shrimp waste, leather shavings and poultry manure. Despite the production of molasses in many countries, its utilisation as animal feed is limited because of alternative uses, export demands and difficulties of transportation and storage. There is great potential in South Asia for more efficient use of AIBP and NCFR for livestock.

Feed deficits exist throughout South Asia as a whole with significant regional variations. However, the extent of this deficit is not very clear because of the methods used to calculate the data. The problems related to feed supply and strategies to match availability to animal needs are complicated by several factors and include straw:grain ratios, variable extraction rates, methods of expression (e.g. tonnes of dry matter or total digestible nutrients), incomplete data sets, and crop residues combined with AIBP, forages and tree leaves. Calculations based on grain yield and grain:straw ratios tend to overestimate the availability of crop residues, when in fact animals use only a proportion of the total produced. In some areas of the Indo-Gangetic plains of India, for example, 80% of rice straw and 40% of wheat straw are burnt after harvest and, therefore, never used for livestock feed (Sidhu 1997). The situation is confused and careful interpretation is required (Jain et al 1996).

In addition, calculations of the nutrient requirements of animals (e.g. cattle), usually based on western standards, tend to inflate their needs, which in turn magnify the deficits. Kelley and Rao (1995) have questioned the increasing shortfall in feeds reported in the literature in India, and suggest that it is highly unlikely that the dramatic increase in bovine production achieved during the last two decades was possible because of the improvement in the feed availability per animal. A comparison of the feed balance for 1967–69 and 1986–88 by Kelley and Rao (1995) shows that, in terms of hectare per animal at the national level, there is a decrease in the area under fodder crops and public grazing lands, whilst the area under fallows has remained constant. However, substantial increases were observed in the availability of cereal straws and AIBP used as concentrate feeds.

The review suggests that there is need for much more rigorous methodologies to address total availability of feed resources for more effective utilisation by animals. This will then allow a clearer focus on the feed deficit problem, the development of strategies to cope with feed constraints that are specific to individual species and production systems, the improved use of the available feed resources (e.g. strategic supplementation), and a definition of researchable issues in animal nutrition in year-round feeding systems. In view of the importance of feed resources as a major constraint to animal production in all countries, the need for urgent research on these aspects cannot be over-emphasised.

Introduction of improved forages

The introduction of improved forage species for ruminants can promote the sustainability of cropping systems, in addition to their feeding value, which is well-documented. Improved forages (particularly legumes) are important to control erosion by providing cover and to increase soil fertility by enhancing nutrient and organic matter levels. Options include under-sowing food crops such as rice with annual herbaceous legumes as inter-crops or relay crops; introducing leguminous leys as sequence crops in rotations; improving natural fallows with legumes; establishing leguminous cover crops in perennial tree crop plantations; and developing agroforestry systems, based on multi-purpose trees, such as alley farming.

Improved pasture species have been evaluated and introduced in all of the countries of South Asia where environmental conditions are suitable. In the subtropical areas of Bhutan, legumes of the genera *Centrosema, Desmodium* and *Stylosanthes* have been tested. Gibson and Namgyel (1991) give an account of the introduction of fodder trees in these areas. In the temperate areas ryegrass, cocksfoot, tall fescue and white clover have been introduced successfully. In India, a wide range of tropical grasses and legumes of the major commercial genera have been tested under rainfed conditions by the various institutes of the Indian Council for Agricultural Research (ICAR) and the state agricultural universities. References in the literature are legion. In Nepal, initial forage development work in the high altitude regions began in the 1950s when ryegrass, cocksfoot and white clover were introduced (Shrestha and Pradhan 1995). In the lower Mid-Hills and Tarai regions Napier grass (*Pennisetum purpureum*), setaria (*Setaria anceps*) and Guinea grass (*Panicum maximum*) were promoted. Napier grass is now grown widely in these areas and oats, vetch and berseem (*Trifolium alexandrinum*) are grown in the winter. Foliage from native trees is used widely in Nepal, and significant collections have been built up at different research stations. Foliage from trees contributes more in the Mid-Hills (63%) than in the mountains (32%) or the Tarai (6%). In certain areas tree foliage may represent up to 80% of the diet of goats for 5–8 months of the year, and about 40% for the rest of the year. Over 500 exotic and indigenous pasture species have been evaluated in Pakistan (Bhatti and Khan 1996). In Sri Lanka, many improved grasses such as species of Brachiaria, hybrid Napier grass and Kikuyu grass (*Pennisetum clandestinum*), and multi-purpose trees such as *Gliricidia sepium* have been introduced over the years (Ranawana and Perera 1995). Chadhokar (1983) and Liyanage (1991) have reviewed fodder development in Sri Lanka. However, farmers in rainfed areas have not adopted these improved forages.

Fodders have been introduced into cropping systems under irrigation, but are mainly restricted to small areas of India (30% of cropped areas in Haryana, Punjab, Rajasthan and Uttar Pradesh) and Pakistan (15% of the cultivated area; 78% in Punjab Province). In India, traditional fodders grown under irrigation in summer include pearl millet, maize, sorghum and cowpea, and berseem, lucerne, rapeseed and oats in winter. Similar species are grown in Pakistan. In Bangladesh, on-farm research is being conducted on the introduction of annual legumes into rice-based systems either as relay crops or catch crops replacing short-term fallow.

There is considerable potential in the region for improved land use and increased income through pasture improvement in forestry plantations and perennial tree crop systems. The grazing of ruminants in forestry plantations is already an important practice in countries such as Bhutan, India and Nepal. The main opportunities in South Asia are the inclusion of cattle and small ruminants under fruit trees and under coconut in southern India and Sri Lanka. Considerable research has been conducted in Sri Lanka on the selection of forages for introduction into coconut plantations (e.g. Liyanage 1993). Where traditional tall varieties are grown light penetration is relatively constant and bright throughout the life of the crop, which benefits the herbage understorey. Non-productive weed species in plantations can be replaced with productive, improved species. However, it is imperative that the introduction of forages and grazing animals into plantations does not interfere substantially with the management of the trees and reduce their yields. Legumes are less competitive than grasses, although there is variation between grass species in their competitive behaviour. Applying inorganic fertilisers can reduce competition, whilst the grazing animals produce manure and promote the cycling of nutrients to improve tree yields.

Manure

Both ruminants and non-ruminants provide manure for the maintenance and improvement of soil fertility. Manure and manure-based composts are used widely throughout the countries of South Asia. Where the use of inorganic fertilisers is low, depletion of soil fertility is a major constraint to agriculture, particularly in the subhumid and humid climates. Even when inorganic fertilisers are applied, crop yields may not be maintained under continuous cultivation on nutrient-poor sandy soils with a low buffering capacity. The use of only mineral fertilisers can decrease soil pH and base-saturation and increase aluminium toxicity. Organic materials applied in bulk can improve soil texture, increase absorption of moisture, reduce runoff and prevent crusting of the soil surface. Small quantities of organic materials can bring about marked improvements in the cation exchange capacity of soils. Even under arid conditions in South Asia, with low and erratic rainfall, the application of manure can play an important role in stabilising or increasing crop yields, improving the utilisation of inorganic fertiliser and enhancing soil fertility (Agarwal and Kumar 1996). Manure is also valuable in reversing the deterioration in soil structure in sodic soils in saline areas, characterised by high contents of exchangeable sodium and low permeability.

Organic manure crops (green manure) have a role in maintaining soil productivity. In South Asia the use of green manure is well-established and widespread. However, in recent times, the advent of high-yielding crop cultivars caused a decline in the use of organic manures in favour of inorganic fertilisers. Now there is renewed interest because of increasing fertiliser costs and a deterioration in soil physical properties. A decline in levels of organic matter is threatening the rice-based systems in Bangladesh and rice–wheat systems on the Indo-Gangetic plain of India. A large number of plants have been used for green manure and include sun-hemp (*Crotalaria juncea*), mung bean (*Phaseolus aureus*), cowpea (*Vigna unguiculata*), guar (*Cyanopsis tetragonoloba*), *Sesbania rostrata* and berseem. Rice-based cropping systems are particularly amenable to green manures which can substitute for up to 60–120 kg fertiliser nitrogen/ha and enhance the availability of other nutrients.

Benefits of crop–animal interactions

It is clear that crop–animal interactions benefit small farmers and contribute to the sustainability of mixed farming systems. Draft animals can speed up operations such as ploughing and cultivating, and increase the land area prepared for cropping. Improved tillage requires extra power for which resources of hand labour are currently inadequate, whilst soil conservation operations such as terracing and ridging are unlikely to be undertaken with hand cultivation. Animals can provide the extra power necessary. The lower compaction resulting from land preparation using animal traction, compared to tractor ploughing, also reduces erosion.

Most buffalo and cattle, and small numbers of goats and sheep in the region are dependant to a greater or lesser extent on cereal straws for maintenance. Straws are sometimes fed during the crop growing season, when animals have little or no access to grazing, and during the dry season when other feeds are in short supply or exhausted. In the dry season, levels of crude protein and phosphorus in the residues of fertilised crops are often two or three times higher than those available from native pasture.

In South Asia, there is a paucity of data on the economic benefits to farmers of introducing animals into cropping systems. This is a reflection of failure to follow a holistic systems approach in research, and failure to assess the economic benefits resulting from interactions rather than the interventions themselves. Nevertheless, a few examples of such benefits can be quoted. In the upland areas of the midlands of Sri Lanka, crop production involves tree crops (coconut and fruit), root crops and herbs. Animals are integrated into about 20% of these farms; cattle (for dairying), goats and poultry. Economic performance for the period 1985–92 for three sizes (1.2, 2.5 and 5.0 ha) of farmer-managed farms showed that dairying contributed most to the total gross profits of 31%, 63% and 69% for the three types of farms, respectively. Animals also contributed significantly to an improvement in soil fertility through manure, and biogas production replaced domestic fuel needs (de Jong et al 1994). The integration under coconut of a mixed pasture based on *Brachiaria subquadripara (miliiormis)/Pueraria phaseoloides* and the multi-purpose trees *Gliricidia sepium* and *Leucaena leucocephala* resulted in increases of 17% and 11%, respectively, in nut and copra yields. The nutrients returned from 73 kg of fresh manure and the application of 30 litres urine/palm per year reduced the cost of fertilising the coconuts by 69%. The system produced sufficient forage to maintain growth and milk yield in the Jersey crossbred animals. The integrated system was viable economically when compared with a monoculture coconut system (Liyanage et al 1993).

Similarly, in southern India, it has been reported from an evaluation of various coconut-based mixed farming systems that it is more profitable to integrate a number of subsidiary crops and animals than to grow coconuts as a monocrop (Das 1991). In this same zone, studies between 1988 and 1993 on a one hactare model farm integrating crops (grain and fodder), silvipasture (trees and grass) and goat-rearing indicated that soil physical and chemical characteristics were all improved, along with the socio-economic conditions of the farmer (Chinnusamy et al 1994).

Animal health and diseases

Diseases are a major constraint to livestock and poultry production in South Asia, and morbidity and mortality can be high. Diseases rank with nutrition and availability of feed resources as the most important constraint to animal production. Common health problems in large ruminants include foot-and-mouth disease, haemorrhagic septicaemia, rinderpest, black quarter and anthrax. The free movement of animals across national boundaries spreads diseases such as foot-and-mouth. Bluetongue and neonatal calf diarrhoea are emerging diseases in some countries, whilst the incidence of tick-borne diseases such as babesiosis and theileriosis are increasing in importance in crossbred cattle. Endoparasitic diseases such as helminthosis are important in small ruminants and buffalo. Sheep pox, pestes des petits ruminants (PPR) and enterotoxaemia cause problems for small ruminants. In poultry Newcastle disease, Gumboro disease, Ranikhet disease, fowl pox and coccidiosis are the most important health problems.

Disease diagnosis and monitoring systems are weak throughout the region, as is the understanding of the epidemiology of the important diseases. There is relatively little information on the incidence of diseases, animal mortality, geographical distribution, seasonality or dynamics, and epidemiological interactions between hosts, disease agents and environment. The use of modern biotechnology for disease diagnosis is limited or absent in the different countries. Socio-economic evaluation of diseases has seldom been undertaken.

Vaccines of one sort or another are produced in all countries, but they are often inadequate to meet national needs. In addition, the quality of some vaccines is poor, and organisations are unable to identify specific strains of infectious agents (e.g. foot-and-mouth disease) for vaccine production. The use of modern biotechnology for the production of recombinant vaccines has yet to be developed satisfactorily in the region. Veterinary delivery systems are also inadequate in many countries. In almost all the countries in South Asia, there is strong interest in the use of indigenous plants in veterinary medicine. Research is being conducted, notably in India, on the classification of plant species, the identification and isolation of active compounds, and the clinical testing of the therapeutic value of these new chemicals. The development of ethno-veterinary medicine could also help to conserve plant biodiversity.

Livestock and the environment

Detailed reports of studies on livestock and the environment have been produced by de Haan et al (1997) and Steinfeld et al (1997). In India and Pakistan, there has been a significant degradation of arid/semi-arid grasslands due to overgrazing. This has resulted in loss of plant biodiversity, reduced yields of pasture biomass, soil compaction, decline in soil fertility and water infiltration, loss of soil organic matter and water storage capacity, and soil erosion. In India, there has been a marked reduction over the years in common property resources as a result of increased cropping. This continuing trend has particular consequences for the large migratory herds and flocks of small ruminants. These animals depend on unimproved grasslands for their nutrition and are contributing to the problem of overgrazing. In seven states in India, from the 1950s to 1982, common property resources decreased by 30–60%. Tree cover was reduced by 75% and there was a decline in grazing days. In Bangladesh, as a result of intensive cropping, negligible areas of native grasslands are now available for grazing. In Nepal, increasing animal populations and uncontrolled grazing have resulted in overgrazing, soil erosion (>40 t/ha per year) and forest degradation in the Tarai, Low- and Mid-Hills regions (Shrestha and Pradhan 1995). In the Himalayan region of Nepal, restrictions on the free access of animals to the native grasslands of China (Tibet) have led to overgrazing of the Alpine pastures in Nepal, and a breakdown of the traditional grazing system.

Although livestock are important in the cycling of nutrients, the pollution of surface water by manure and seepage of surface discharges are a problem in peri-urban and urban production systems. In the large urban milk colonies (e.g. in Karachi, Pakistan) manure accumulates daily in very large quantities and is never removed from the area. In addition to risks for human and animal health, it represents a waste of valuable organic matter and nutrients for crop production. Concerns have been expressed about the contribution of livestock in India to global methane production. Efforts are now being made to reduce methane production through more efficient feed utilisation.

Further pollution is caused in South Asia by the concentrated and unregulated processing of animal products. Slaughtering requires large amounts of hot water and steam for sterilisation and cleaning. Therefore, the main polluting component is waste water, which contains biodegradable organic compounds requiring oxygen for degradation, as well as insoluble inorganic and organic compounds. Tannery effluent, another pollutant, is discharged into inland surface water sources or is used for irrigation. High concentrations of salt and hydrogen sulphide greatly affect the quality of water, whilst suspended matter (lime, hair etc) makes the surface water turbid and settles at the bottom affecting fish. Chromium tannin is toxic to aquatic life. When mineral tannery waste is applied to the land, soil productivity is affected adversely as is the groundwater due to infiltration.

However, peri-urban and urban livestock in South Asia are frequently on the receiving end of environmental pollution. In India, fluorine and heavy metals such as lead from industrial plants cause serious toxicosis (fluorosis and plumbism) in cattle in the cities. In Pakistan, cattle and buffalo in dairy colonies (e.g. Karachi) are fed cottonseed cake heavily contaminated with pesticides and waste bread from the city that contains aflatoxins. These pollutants pass into the milk which is sold untreated in the city of Karachi.

Socio-economics and policy

Socio-economic and policy issues related to livestock appear to have received limited attention from research workers except dairy cattle development that received the greatest emphasis in South Asia. This is reflected in the number of socio-economic studies. Rarely have other species or non-dairy issues been addressed in socio-economic terms.

National livestock development plans often make mention of poverty alleviation, employment generation, food security and nutritional improvement as their goals. A small number of studies have shown empirically that livestock, especially dairy animals, have increased income and employment, and helped to reduce poverty (Alderman 1987; Mergos and Slade 1987; Doornbos et al 1990; Somjee and Somjee 1990; Viswanathan 1992; Huq 1994; Thirunavukkarasu et al 1994; George 1996). In all of the countries, livestock ownership is more egalitarian than land ownership as many landless farmers own livestock. Livestock have contributed to a reduction in income inequality and poor farmers prefer to invest in livestock than in anything else, particularly dairy animals, as a means to improve their asset and income situation (Verma and Malik 1991; Adams and Alderman 1992). Some studies have shown that general rural and infrastructure development help investment in livestock as well as enhancing the demand for livestock products (Ahmed and Hossain 1990).

'Operation Flood' in India is the most publicised and the largest dairy development programme in the region, although other countries have implemented similar projects in a more modest way. The dairy co-operatives in India have played a significant role in improving production and marketing efficiency and in serving the poor rural producers and urban consumers (Alderman 1987; Mergos and Slade 1987; Doornbos et al 1990; Somjee and Somjee 1990; George 1996; Arora and Bhogal 1997). However, some studies, whilst emphasising the positive role played by Indian dairy co-operatives, have highlighted the development opportunities lost as a result of the monopoly. The reasons for unequal development of dairy co-operatives in different parts of the country are also highlighted (Doornbos et al 1990; George 1996; World Bank 1996; Anon 1997). Studies assessing marketed surpluses have generally found a higher percentage of these in areas covered by co-operatives. The management implications of widely dispersed smallholders selling small quantities of milk to co-operatives have also been examined, as well as the inability of dairy co-operatives to eliminate small, private milk traders. These market surplus studies have shown that private traders function efficiently than co-operatives because the traders provide some services such as a higher rate of frequency of payments, more flexible method of payments and advances on purchases which co-operatives often do not provide (Shah 1983; Doornbos et al 1990; Arora and Bhogal 1997). There are few examples of marketing and price analysis of live animals and meat, the exceptions being Sharma and Vashist (1995) and Talukdar and Singh (1995).

Many NGOs are involved in rural development and agricultural activities but few have programmes for livestock development. Experiences of some of these NGO activities have been described (Satish and Farrington 1990; Huq and Sabri 1992), but their impact has not been adequately assessed. Livestock credit is generally less accessible than credit for crop technologies, although some NGO in Bangladesh are changing this situation. However, there are a few examples of analysis of supply of credit and its effects on livestock productivity and technology adoption (Alam et al 1993).

Demand for animal products will grow due to income growth, population growth and urbanisation. However, the development of strategies to meet increased demand will require specific information on the pattern of demand and its changes across zones and regions in each country according to income and social class. Social and cultural factors also influence which species of animals are produced, by whom, and where to meet market demand. In the few examples of food-demand analyses that exist, demand for animal products is not analysed in a sufficiently disaggregated manner to be useful to guide technology development and investment in livestock (Jain et al 1992; Hazel and Bhalla 1996).

Almost exclusively, farming systems research has generated publications describing cropping systems and, in rare cases, some component technologies that involve livestock. Little work has been conducted to quantify or model the interactions amongst components of a farming system, and the possibilities for improvement through interventions of one kind or another (Hermans 1985; Lensch 1990; Vijayalakshmi et al 1993; Gaddi and Kunnal 1996; Maikhuri 1996). A number of studies have analysed the economics of resource use in dairy production with the performance of well-managed crossbred cows compared to local cows raised under traditional management. Some work has assessed feed availability and demand, and reported the development of feed markets to mitigate spatial imbalances in feed supply and demand. However, these studies did not assess the efficiency of the emerging feed markets (Kelley and Rao 1995). A failure to conduct systems-oriented research has meant that results are not client-oriented, and do not meet the needs of smallholders or the landless. Some adaptive research, targeted at smallholders, in development programmes such as 'Operation Flood' in India have succeeded in making an impact (Doornbos et al 1990; World Bank 1996).

Extrapolation of results of location-specific experiments for wider geographical conditions is often constrained by the lack of any mechanism for integrating and standardising information from various locations and sources. Some effort has been made in India to bridge the gap by developing databases and software to synthesise results from various sources (Maru et al 1993).

Post-production systems

Aspects of post-production involving the handling of animals, transportation, slaughter, storage and processing is an area that is addressed weakly by research organisations throughout South Asia. One notable exception is the work of the Central Leather Research Institute (CLRI) in Chennai, India. The CLRI has worked with several international organisations and economic studies have been conducted. These studies include resource assessment of the leather and allied sectors, livestock management and marketing, slaughterhouse management and the marketing of meat and other by-products (hides, skins and leather). An example of a useful output is the report on an all-India survey of raw hides and skins (CLRI 1987).

Conclusions

Crop–animal systems

There is a paucity of information on farming systems research that incorporates animals interactively with cropping systems. Research on component technologies emphasising animal nutrition was very common. The methodologies for analysis of crop–animal systems are generally weak, and little research has been conducted on most aspects of socio-economics.

Three main animal production systems are identified. Extensive systems where pastoralism is practised; those where animals are integrated with cropping in rainfed and irrigated areas; and systems associated with perennial tree crops (mostly coconut).

Important interactions occur between crops and livestock in all countries. However, data on the benefits of crop–animal interactions are limited. Data from two long-term studies in Sri Lanka indicated increased productivity, higher income and improved sustainability from mixed farming.

Animal genetic resources

Considerable biodiversity exists in breeds within given species in South Asia. However, characterisation of these indigenous breeds has been limited, and many are threatened by genetic erosion. Crossbreeding of indigenous cattle with exotic animals for milk production is widespread, and has contributed to the relative neglect of indigenous breeds.

Feed resources and nutrition

A major constraint to the production systems is the availability of feed resources. A wide range of feeds are available that include native grasslands, improved forages, crop residues, AIBP and NCFR. Rangelands are an important feed resource in South Asia and significant areas are found in the arid/semi-arid zones of India and Pakistan, and in the hills of the Himalayan region. Crop residues make a very significant contribution to animal feed requirements in the mixed farming systems. Several studies in various countries have attempted to quantify their availability. However, there are inconsistencies in the estimates, and the methodologies used to derive these values are not clear. The urgent need for much more rigorous methodologies to address total availability of feed resources is emphasised. A feature in all countries is the presence of feed deficits. Virtually no work has been conducted on synchronisation of various feed options with the nutritional requirements of animals in different ecological systems throughout the year.

A wide range of improved grasses and herbaceous legumes have been evaluated over a long period of time in the subtropical/tropical and temperate zones, and for rainfed and irrigated conditions. Only in irrigated systems has there been some adoption. Studies with multi-purpose trees in subtropical/tropical zones have emphasised *Gliricidia sepium* and *Leucaena leucocephala.*

Animal health

Diseases are also a major constraint to animal production. A wide range of diseases affect livestock and poultry in South Asia. Disease diagnosis and monitoring systems are weak, in view of understanding of the epidemiology of important diseases. Vaccine production is often inadequate to meet needs, and vaccines are usually produced without modern biotechnology and are of poor quality. Veterinary delivery systems to farmers are weak.

Livestock and environment

Overgrazing is a problem in the arid/semi-arid zones and in the Himalayan region. Pollution of surface water by manure occurs in peri-urban and urban production systems. Further pollution is caused by the unregulated processing of animal products.

Socio-economics and policy

Profitability of crossbred cows over local cows, and the marketing efficiency of dairy co-operatives are the two main areas that have received most attention. Minor attention has been given to the demand for livestock products, mechanisation and its consumers, marketed surpluses of dairy products, and access to credit. The impact of livestock development projects and of macro and sector policies on incentives for the domestic livestock subsector have received no attention.

Post-production systems

Very little research has been conducted on aspects of post-production involving the handling of animals, transportation, slaughter, storage and processing.

4 Field assessment of crop–animal systems

Introduction

This section presents an integrated report on crop–animal systems in the six countries visited, namely Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Detailed information on animal agriculture in these countries is found in Appendix I. The sections on animal health were provided by experts from the national programmes in each country.

The visits to individual countries provided valuable insight into the major constraints to production, the research priorities, the extent of work done or underway, and the future research direction for livestock improvement in crop–animal systems in the AEZs. These visits also helped clarify and update the desk review undertaken initially, and provided a sharper focus on the potential opportunities for research, knowledge of the institutions and research capacity. Ultimately, the visits helped identify the common major constraints to production in mixed farming systems and define the researchable issues.

Environment and cropping systems

Detailed classifications of AEZs are available for most countries, but the systems used for classifying components such as climate and soils lack consistency. Much of South Asia is characterised by dry climates, in which total precipitation and its distribution limits plant growth. The exceptions include Bangladesh, parts of north-west, eastern and southern India and south-west Sri Lanka where humid climates occur. Many of the soils are of low fertility with low levels of available nutrients and organic matter. Vertisols present special problems of management. In the arid/semi-arid zones of India and Pakistan wind erosion can be a problem. On cultivated sloping land in the mountainous areas of Bhutan and Nepal erosion is caused by the runoff of rainfall. Salinity is a problem in irrigated areas in India and Pakistan, and in the coastal regions of Bangladesh.

In Bangladesh, India, Nepal and Sri Lanka, rice-based systems (rainfed and irrigated) are the most common cropping systems. In Pakistan, wheat-based systems (rainfed and irrigated) dominate and in Bhutan, maize-based systems (rainfed) are important. Rice–rice and rice–wheat cropping patterns cover a large area. Irrigated agriculture is more widespread than rainfed agriculture in Pakistan and Sri Lanka. In every country, rice is one of the three major crops; wheat is one of the three major crops in four of the countries. After rice and/or wheat, pulses are the major crops in India; pulses and oilseeds in Sri Lanka; cotton in Pakistan; jute in Bangladesh; and maize in Nepal. Both single and multiple cropping patterns are common with inter-cropping, relay cropping and sequential cropping being practised. Shifting cultivation is not a major system in the region.

Animal genetic resources

Large and diverse populations of livestock occur in all the countries, but particularly in India and Pakistan. However, there has been little characterisation of indigenous breeds and many are described simply as 'nondescript'. Species vary in their distribution within and between countries, and in their population sizes. The use of the indigenous genetic resources is largely focused on the large ruminants (buffalo and cattle) for milk production, followed by beef (except Bhutan, India and

Sri Lanka) and then draft power. In India and Pakistan, the buffalo reigns supreme for milk production. In India, a smaller population of buffalo, relative to cattle, produces about 55% of the total milk output. In Pakistan, 70% of the total milk production comes from the buffalo with an annual population growth rate that is over three times that for cattle (2.4% versus 0.7%). Despite the presence of such outstanding buffalo breeds such as the Kundi, Nili-Ravi and Murrah for milk production, limited attention has been given to their improvement through selection. Some effort is now underway in India and Pakistan, but is generally a small-scale activity. The Nili-Ravi and Murrah breeds from both India and Pakistan have been exported to Bangladesh, Nepal and Sri Lanka, and to the countries of South-East Asia for crossbreeding with the swamp buffalo. This has resulted in a triple-purpose animal (draft, meat and milk).

The use of buffalo and cattle for milk is often complementary, e.g. in Pakistan. When buffalo are dry, cows are lactating and vice versa. Cattle are important for draft in Bangladesh, India and Pakistan and buffalo in Sri Lanka. In the Himalayan regions of Bhutan and Nepal, mithun and yak are used for draft power.

With cattle, crossbreeding to improve milk production is widespread in all countries. Indigenous breeds are crossed indiscriminately with mainly the Holstein-Friesian through artificial insemination. However, crossbreeding policies are not well-defined and are unco-ordinated, particularly with regard to the control of levels of exotic blood in crossbreds at the farm level. In India and Pakistan, it has now been decided that crossbreeding with the Holstein-Friesian should only take place in areas where feed resources are abundant. In more marginal areas, the Jersey should be used for genetic improvement. Furthermore, the indigenous Red Sindhi and Sahiwal breeds will no longer be included in crossbreeding programmes.

One consequence of crossbreeding has been genetic erosion in the more important indigenous breeds, especially those used for dairying such as the Red Sindhi and Sahiwal. In Pakistan, for example, crossbreeding has reduced the population of the Sahiwal pure-breds to dangerously low levels from centre of origin. Breeds needing characterisation and conservation are the Dhanni, Gir, Lohani and Tharparkar. After 25 years of crossbreeding in India and Pakistan it is difficult to identify pure-breeds. The breeds of India are now described by scientists in ICAR as 'mongrels'. The overall situation in all countries is that crossbreeding programmes are in a state of some chaos.

With small ruminants, crossbreeding has also been important in experimental terms, and European and Australian breeds have been introduced to improve wool and mutton. Notable amongst these breeds are the Merino, Suffolk and Dorset Horn that are used to produce various 'synthetic breeds'. Improved productivity is apparent, but none of the crossbreds have been adopted by farmers. In goats, the Saanen and Alpine breeds have been introduced and crossed with indigenous breeds to increase milk production, and the Angora to improve fibre production. Again, the success rate has been variable. In small ruminants, within-breed selection has been very limited. In India, attempts are being made to make better use, in crossbreeding programmes, of superior indigenous breeds such as the Jamnapari. These have also been introduced into other countries in South Asia and also into South-East Asia.

Animal production systems

Visits to the six countries confirmed the importance of crop-animal systems and the multiple roles played by livestock. Similar systems occur throughout the region but vary in relation to AEZ, feed type and availability, the intensity of mixed farming operations and the response to market opportunities. The relative populations of individual animal species are dependent on their different functions, the demand for food products and their socio-economic contribution.

Buffalo and cattle are particularly important in both the rainfed and irrigated cropping systems, where greater supplies of crop residues and AIBP are available and manure and draft animal power are required. Milk production is also very important in the intensively cropped areas. Although small ruminants are found in these systems, more important concentrations are found in the extensive pastoralist and agro-pastoralist systems where nomadism and transhumance are practised. However, in southern India, intensification is beginning to take place through the development of intensive stall-feeding systems. Chickens are more important than ducks, and pigs are common in the scavenging systems in non-Muslim countries. Poultry production is becoming increasingly more intensive in the region, although scavenging systems are widespread in rural areas. Aquaculture is most commonly practised in Bangladesh. The integration of crop production with non-ruminants is very limited in contrast to South-East Asia. Ducks have been integrated into rice–fish systems in Bangladesh, in some coastal areas of India, and in Sri Lanka. In Bangladesh, goats have also been integrated into these systems and, in Sri Lanka, vegetables.

Extensive grazing systems are common in the arid/semi-arid rangelands in India and Pakistan. In the Himalayan region of Bhutan and Nepal, Alpine pastures are very important as feed resources and there is no integration with cropping. In Bangladesh, extensive grazing systems do not exist. Nomadism and transhumance are associated with the extensive systems. In both major zones, small ruminants and cattle are the most important species. Camels are raised in the dry areas, and mithun and yak in the highlands.

Systems integrating livestock and perennial tree crops are significantly less important than in South-East Asia. Nevertheless, there are areas of coconut in southern India and in Sri Lanka. In Sri Lanka, large and small ruminants graze unimproved pastures under the coconut, and there are clear opportunities for improving the system. However, only one example was seen where leguminous-cover crops were established under coconut. Grazing under fruit trees was not common in the region but, given the extensive areas of these crops, e.g. in Punjab Province (Pakistan), there is a great deal of potential for development of integrated systems.

Peri-urban and urban dairy production systems are very important in the cities of India, Nepal and Pakistan, and represent a trend towards intensification. However, major interactions between animals and cropping are less obvious in these systems. Some manure is used for fuel, but most of it is wasted and represents a major loss of nutrients for crop production. There is some movement of roughages (crop residues and green forages) from rural areas to the peri-urban and urban areas, but the larger dairy colonies use significant amounts of waste bread from the cities, concentrate feeds and relatively little roughage. The movement of buffalo and cattle from rural areas to peri-urban and urban areas does not constitute an interaction. However, this movement of better animals to the city areas and their subsequent slaughter at the end of their lactation periods is a loss of valuable genetic material in effective breeding programmes.

Feed resources

Four main categories of feed were found in all of the countries. These were fodders (native and improved grasses, herbaceous legumes, forage crops and multi-purpose trees), crop residues, AIBP and NCFR. Inventories of the type and quantities of feed exist for all countries except Bhutan.

Forage crops and improved grasses and legumes, grown specifically for livestock, represented only a small component of the available feed resources despite an emphasis on forage research in every country. These were observed mainly in the irrigated farming systems in India and Pakistan and consisted of berseem, oats and mustard/rapeseed. In Bangladesh, no forage crops are grown in cropping systems. In Pakistan, chopped sugar-cane was being fed to large ruminants in the irrigated areas of Sindh Province. In Sri Lanka, the multi-purpose tree *Gliricidia sepium* is used widely by smallholders, and foliage from a wide range of native trees is collected in many countries for animal feed. Varying amounts of native pastures exist in the different countries, with the largest areas of rangelands being found in the drier zones of India, Pakistan and northern Sri Lanka. Native Alpine pastures are found in the Himalayan regions of Bhutan, India, Nepal and Pakistan. Important forage resources also exist in the forest areas of Bhutan, India and Nepal and under coconut in southern India and Sri Lanka. In Bangladesh, intensive use of land for cropping has almost eliminated the native grasslands. In other countries grazing areas are declining and land degradation is evident.

Residues of a wide range of crops, especially rice and wheat, are the major feed resource in mixed farming systems in all countries visited. Due to feed shortages, NCFR are used in many countries and include unusual feed categories such as leather shavings, duckweed and tea waste. A wide range of AIBP are available in every country, but these together with NCFR contribute <10% of feed requirements. Currently, much of the vegetable protein meals such as groundnut meal, soyabean meal and copra cake produced are used to feed non-ruminants. Cottonseed and sunflower cakes are used for feeding lactating ruminants. Much research has been undertaken in Bangladesh, India, Nepal, Pakistan and Sri Lanka on the development and use of multi-nutrient urea–molasses blocks as feed to provide a better balance of nutrients for all ruminants. However, availability and cost often limit the widespread use of the blocks. In India, urea–molasses blocks are being exported to neighbouring countries.

In most of the countries visited, component technology interventions are mainly in the area of feed resources. In all countries, notably India, Nepal, Pakistan and Sri Lanka, considerable research has been conducted on the treatment of rice straw with urea or ammonia for ruminants. A huge information base has been accumulated on the improvement of nutritive value. However, the adoption of this technology at the farm level has been very poor for a variety of reasons, including cost and social relevance. Research on technology delivery at farm level and the assessment of social, economic and environmental impacts is very weak. The participation of farmers in the development of research work was non-existent.

The increased populations of ruminants in rural areas has not been matched with parallel increases in the quantity and quality of feed resources, despite a greater availability of crop residues. The best feeds are often channelled to peri-urban and urban areas for dairy production.

Animal health and diseases

The visits to the six countries confirmed the importance of the diseases reported (foot-and-mouth, haemorrhagic septicaemia, rinderpest, black quarter and anthrax) from the literature in Chapter 3. The same diseases occurred throughout the region, although their relative importance varied between countries. In general, diseases were identified as first or second priority along with the availability of feed resources. In addition, perceived weaknesses were confirmed in disease diagnosis and surveillance systems and epidemiological research, together with the limited or lack of use of biotechnology for disease diagnosis and vaccine production and deficiencies in veterinary delivery systems. It was clear in all countries that the uncontrolled movement of animals across national boundaries is causing major problems for control of infectious diseases such as foot-and-mouth. Research involving interactions between animal health and nutrition/management/genotype is non-existent.

The use of medicinal plants to treat internal parasites, metabolic and skin diseases is well developed in a number of countries, and is an area of growing interest although the knowledge base is still weak. Effective research efforts are underway particularly in Bangladesh, India and Pakistan to identify valuable plants, isolate and test the active ingredients.

Socio-economics and policy

Government policies in every country are biased towards crop production and, in some instances, adversely affects the livestock subsector. The primary focus of government efforts in ruminant livestock development in all the six countries has been dairy development through crossbreeding. However, the overall impact of dairying on income, employment, food security, gender roles, risk and resource management and the environment have not been fully addressed. In some parts of India, co-operatives have played a significant role in dairy development by providing market outlets for milk at stable prices and supplying inputs and services to smallholders in dispersed areas. In other parts of India and in the other countries where co-operatives did not make any headway, market failure and lack of supporting infrastructure have created two undesirable consequences on the domestic dairy industry. First, dispersed smallholder rural dairy producers remain disconnected from the potential urban consumers. Second, small- and large-scale dairying is emerging in peri-urban and urban areas nearer to the consumer, which may have serious negative consequences (for example through pollution) on public health and the environment.

In India, co-operatives are protected by the National Dairy Development Board (NDDB) through a near monopoly rights on national dairy policy concerning imports and tariffs as well as price and marketing in the domestic sector. In areas without dairy co-operatives, and in many peri-urban areas where co-operatives are present, private milk traders are also functioning. The role of private enterprise in the livestock subsector in general, and dairy production and processing in particular, needs to be assessed objectively.

There was little evidence that research workers in the countries visited considered client needs and preferences in designing their experiments for technology development. The process of livestock technology transfer is weak, so adoption of new technologies is poor across the region. Similarly, analyses of the demand for animal products and consumer preferences were also neglected.

Animals are still the primary source of power for crop production in all the countries in the region. However, feed constraints and liberal economic policies have made mechanical power more competitive than draft power, particularly in the irrigated areas. The consequences of this on many aspects of the livestock subsector are not yet clear.

Access to credit for livestock activities is inadequate and more difficult to obtain than credit for crop technology adoption. However, some NGO and government programmes in all the countries are increasingly giving more attention than in the past to poverty alleviation and food security for the poor, particularly the landless and women, through provision of credit for livestock. Given their poor resource endowment, most of these borrowers engage in poultry and small ruminant production and in some cases dairy production. However, the impact of these credit programmes on livestock productivity has yet to be established empirically.

In all the countries, veterinary services and inputs are still in government hands and are provided at heavily-subsidised costs. Some pilot studies have been conducted to test the suitability of privatising some services and charging users for other services. However, there is no clear policy direction yet on the optimal balance between private and public sector roles in the delivery of health services, or pricing policy for these services.

The countries in the region have adopted liberal economic policies at different points in time, and the degree of liberalisation practised also varies across countries. However, trade among neighbours is limited. Bangladesh and Sri Lanka import large amounts of powdered milk from outside the region and a small amount from India. India also exports live animals and meat to South-East Asia and to countries in the Middle East. However, under the emerging liberal global trade policies, the countries in the region need to examine the comparative and competitive advantages of the production of livestock and livestock products as well as feeds for livestock. The feed production potential of India deserves attention since low quality grains may be increasingly less preferred for human consumption with rising income, and the areas where such crops are grown may not be suitable for others. Analysis of the impact of trade and macro-policies on the domestic livestock subsector also need investigation in view of the recent decision to establish a South Asian Association for Regional Cooperation (SAARC) and South Asian Preferential Trade Agreement (SAPTA).

Institutions and research capacity

The types of institutions and organisational structures involved with research in each country are presented in Table 9. There are five categories of organisational structures based on the classification of Trigo (1986), viz. (a) the Ministry model (b) the Autonomous or Semi-Autonomous Institutes model (c) the University model (d) the Agricultural Research Councils model and (e) Private Sector Research Organisations. Good examples of (a) are the Veterinary Research Institute in Sri Lanka and the Ministry of Agriculture in Bhutan, (b) ICAR, (c) the state agricultural universities in India, (d) the Bangladesh Agricultural Research Council (BARC), the Pakistan Agricultural Research Council (PARC) and the Nepal Agricultural Research Council (NARC). Private Sector Research Organisations include NGOs and private entrepreneurs who are associated with veterinary inputs such as drugs and vaccines, as well as products such as meat, milk and eggs. The NGOs are particularly strong in Bangladesh and India.

Table 9 also provides an assessment of research capacity based on several elements including research infrastructure and facilities; publication record and output; research publications, focus and relevance; track-record and impact; farming systems research priorities; linkages with clients, extension, and technology delivery; human resource availability and capacity; and linkages with donor funding. India has been ranked as good in research capacity, mainly because of the considerable research that has been undertaken, the manpower availability and the facilities. Bhutan has the weakest research system in South Asia. In some countries research organisations spend too much time fulfilling service functions rather than conducting research. In all countries, researchable issues in the social sciences are poorly addressed. A feature in Bangladesh, Bhutan, Pakistan and Nepal is poor information exchange and inadequate access to literature sources such as international journals, new books and proceedings from workshops and conferences. Often research scientists are unaware of new developments in science and technology unless they have opportunities to travel. This is a major constraint to the development of effective research and development programmes.

Table 9. *Institutions, organisational structures and research capacity in South Asia.*

	Category of institution[1]					
	a	b	c	d	e	Research capacity[2]
Bangladesh			+	+		++
Bhutan	+					+
India		+	+	+	+	++++
Nepal			+	+		++
Pakistan	+		+			++
Sri Lanka	+		+	+		++

1. (a) The Ministry model; (b) Autonomous or Semi-Autonomous Institutes; (c) Agricultural Research Councils; (d) The University model; (e) Private Sector Research Organisations.
2. +++++ Strong; ++++ Good; +++ Average; ++ Weak; + Minimal.

Much of the research conducted by the NARS in all countries is component-oriented and lacks multi-disciplinarity and a farming systems focus. In many institutions natural resource management issues are neglected and there exist disciplinary barriers between the soil, plant and animal sciences which preclude a holistic approach. In addition, there is also an unfortunate rift between veterinarians and animal scientists. Research programmes often lack leadership by experienced scientists and fail to focus on the problems that need to be addressed. Priority setting is very weak in all countries. There is an urgent need for multi-disciplinary, systems-oriented research to address the major constraints to production. For crop-animal systems research to be applied more forcefully, research capacity in many of the NARS will need to be strengthened.

Information systems

Information systems, particularly storage and dissemination, is variable in the countries visited. It is strong in India, average in Bangladesh, Pakistan and Sri Lanka and weak in Bhutan. The dissemination of information can be improved considerably, within and between countries, to enhance research relevance and project formulation.

Conclusions

The assessment of crop-animal systems through field visits to individual countries led to the following conclusions:

1. Cropping patterns based on rice and wheat dominate in the region under both rainfed and irrigated conditions. Both single and multiple cropping patterns are practised.
2. In India and Pakistan, most of the milk is produced from buffalo, although only limited attention has been given to its improvement through selection. In cattle, crossbreeding with temperate breeds is widespread and uncontrolled. Considerable genetic erosion of indigenous breeds has taken place with all species of livestock.
3. The importance of crop-animal systems and the multiple roles played by livestock have been confirmed in every country. Similar systems occur throughout the region but vary in relation to AEZ, feed type and availability, the intensity of mixed farming operations and the response to market opportunities. Buffalo and cattle are most associated with these systems. Small ruminants are of particular importance in extensive rangeland grazing systems in dry areas and at higher altitudes.
4. Availability of feed resources emerged as a major technical constraint to production. Feed deficits occur in all countries. Crop residues are the main feed resource in mixed farming systems, and improved forages have only been developed to a limited extent principally in irrigated areas. Component technology interventions in the area of feed resources have been attempted, but farmer adoption has been poor.
5. The major animal diseases are the same in all countries and rank with feed resource availability as a major technical constraint to production. A wide range of diseases are prevalent and there are weaknesses in disease diagnosis, vaccine production and veterinary service delivery systems. Epidemiological studies have not been undertaken to a significant extent. There is a growing interest in exploiting the use of medicinal plants in veterinary medicine.
6. Socio-economics and policy issues have been neglected and more research is needed in these disciplines.

7. Much of the research conducted by the NARS lack a farming systems perspective, and disciplinary barriers exist in all institutions. Research capacity in the NARS varies from minimal to good, but priority setting is weak. Opportunities exist for better information exchange.

Having concluded a review of literature and visits to the six countries of South Asia, it is of interest to draw attention to the contrasts and commonalties with South-East Asia. These include the following:

- The incidence and levels of poverty are much greater in South Asia making issues of poverty alleviation and food security more critical.
- The main AEZs of South Asia are arid/semi-arid, whilst those of South-East Asia are subhumid/humid.
- Increasing human and animal population densities and greater pressures on available land make integrated natural resource management more complex than in South-East Asia.
- Rangelands in the arid/semi-arid zones and areas of native grassland in the Himalayan regions are more significant in South Asia because of the aridity and cool temperatures. Nomadism and transhumance are practised in these areas.
- Shifting cultivation is only practised in small areas of South Asia and is, therefore, not a major system.
- Irrigated cropping systems in South Asia show more diversity, including the integration of fodder crops.
- Crop–animal systems involving annual and perennial crops are found in both regions. However, systems integrating tree crops/ruminants and annual crops/non-ruminants/aquaculture are more common in South-East Asia.
- The size and diversity of the animal populations are much greater in South Asia. Furthermore, the number of indigenous breeds within species is larger. There has been much more emphasis on crossbreeding in South Asia, particularly with dairy cows, and a greater genetic erosion of the indigenous breeds.
- Intensive dairy production, using both buffalo and cattle, is more advanced in South Asia. Landless urban and peri-urban production is also more important.
- Feed deficits in South Asia are more critical than in South-East Asia.
- Animal health and feed resource availability alternate as the major constraint to production in the countries in South Asia. In South-East Asia, availability of feed resources was consistently the main constraint.
- A greater emphasis is placed on the exploitation of medicinal plants in veterinary medicine in South Asia.

Irrespective of the differences, there are several commonalties that provide important linkages between the two regions. These include weaknesses in the research prioritisation process, the importance of animal feeds and animal health as major constraints to production, the lack of a farming systems approach to research, the development of peri-urban dairying, the integration of livestock with annual and perennial cropping systems, and the limited use of improved forages and multi-purpose trees. Several issues in the areas of socio-economics and policy, training, information exchange, and the need to strengthen research capacity are also common to both regions.

5 Key researchable issues in crop–animal systems

Introduction

Based on the information presented in the previous chapters on the characterisation and importance of agro-ecological zones (AEZs), the review of the literature, the assessment of the status of research on and development of crop–animal systems and research opportunities, the key researchable issues can now be identified.

A summary of the existing situations in the two target AEZ (arid/semi-arid, subhumid/humid) relating to the resource base, agricultural production systems and feed resources is presented in Table 10. The key researchable issues in these areas are also discussed. Animal genetic resources, animal health and diseases, socio-economics and policy, and training and information exchange are cross-cutting issues. The existing situation and research and training needs in these areas are also highlighted. These key researchable issues are not arranged in any order of importance.

Table 10. *Key researchable issues in the arid/semi-arid and subhumid/humid AEZs.*

Arid/semi-arid zones		
Themes	Situations	Researchable issues
1. Resource base	High demand for water resources	Assessment of economic and environmental impacts of development
	Length of growing period 0–179 days	Evaluation of efficient resource management options
	Salinity problems in soils under irrigation	
	Fragile environment with soils of low fertility	
	Land degradation due to nomadism/transhumance, tree removal and overgrazing	
	Human population density low and incidence of poverty and food insecurity high	
	Adoption of improved livestock technologies variable and generally poor across countries	
	Inadequate interdisciplinary research on natural resource management	
2. Agricultural production systems	Annual and perennial crops grown under rainfed and/or irrigated conditions. Irrigation is advanced	Systems dynamics, determining forces and possible future development
	Crop–livestock systems important	Technologies for sustainable crop–animal systems. Beef production potential from buffalo and male cattle
	Relatively higher populations of buffalo than cattle	Improvement of calf production systems
	Dairy buffalo populations increasing, draft cattle decreasing	Socio-economic and environmental impact assessment of pastoralism
	Development of market-orientated smallholder dairying due to co-operatives and/or other infrastructural support	Modelling of integrated natural resource management

Arid/semi-arid zones

Themes	Situations	Researchable issues
	Goats and sheep are mainly under pastoralist systems interfacing with mixed farming	Role of goats and sheep in improving systems integration and resource management
	Poor animal management	
3. Feed resources	Feed deficits	Synchronisation of feed supplies with year-round animal requirements
	Poor quality feeds	Effects of changing cropping patterns on feed production strategies
	Forage production in irrigated areas where dairying is developed	Improving quality of crop residues through plant breeding
	Inadequate use of AIBP and NCFR in urban/peri-urban dairy production systems	Strategic supplementation
	Some use of multi-purpose trees	Identification of anti-nutritional factors and medicinal value of fodder trees
		Development of methodologies for evaluation of feed resource availability and animal demands

Sub-humid/humid zone

Themes	Situations	Researchable issues
1. Resource base	Length of growing period 180–270 days	Development of strategies for reduction of erosion in uplands
	Adequate water resources	Development of sustainable production systems
	Human population density high, poverty and food insecurity high	
	Natural resource management problems in upland areas	
	Inadequate interdisciplinary research on improved natural resource management	
	Adoption of improved livestock technologies variable and generally poor across countries	
2. Agricultural production systems	Rice- and wheat-based farming systems involving ruminants and non-ruminants, also fish in some places	Development of methods for integration of multiple enterprises for sustainable production systems
	Draft buffalo and cattle populations increasing, dairy cattle and buffalo numbers marginally increasing	Socio-economic and environmental impact assessment of integrated systems
	Poor animal management	Component technology development through systems analysis
	Multiple cropping common, manure is an important source of nutrients	Improvement of calf production systems
	Market-orientated smallholder dairying less developed due to lack of marketing and infrastructure	

Sub-humid/humid zone

Themes	Situations	Researchable issues
	Animals commonly tethered or stall-fed	
	Relatively small areas under tree–crop systems, mainly coconut and fruits. Coconut integrated with small ruminants and cattle	
3. Feed resources	Tables of feed composition available in most countries	Development of methodologies for evaluation of feed resource availability and animal demands
	Feed deficits	Synchronisation of available feed resources with year-round animal requirements
	Considerable research on treatment of cereal straws	Strategic use of protein supplements in the dry season
	Inadequate information on utilisation of NCFR and importance of anti-nutritional factors	Methodologies to improve processing of forage protein sources to increase nutritive value
	Inadequate protein supplements	Testing wider range of pest-resistant multi-purpose tree germplasm
	Improved grasses and legumes available	Constraints to adoption of improved forages
	Large amounts of understorey herbage and copra cake available as feeds in coconut plantations	Development of complete feeds for stall-feeding systems
	Some use of multi-purpose trees	

Cross-cutting themes

Themes	Situations	Researchable issues
1. Animal genetic resources	Considerable diversity in well-adapted breeds within species	Characterisation of indigenous breeds
	Inadequate characterisation, use and improvement of indigenous species and breeds, evidence of genetic erosion in indigenous breeds	Objective assessment of crossbreeding programmes
	Crossbreeding programmes without defined objectives and policies	Assessment of farmer knowledge and preference for species and breeds
	Farmer knowledge and preferences about species and breeds not assessed	
2. Animal health and diseases	Uncontrolled movement of animals across borders spreads infectious diseases	Studies on epidemiology and economics of major diseases
	Poor veterinary services and inputs in all countries	Pathogen identification and improved disease control
	Few studies on helminthosis and helminth resistance in small ruminants	Studies on disease–nutrition interactions
	Disease diagnosis and surveillance generally weak	Studies on genetic resistance to diseases
	Foot-and-mouth disease, haemorrhagic septicaemia, anthrax, black quarter and rinderpest important in large ruminants	Assessment of balance between private and public sector involvement in the delivery of health services

Cross-cutting themes

Themes	Situations	Researchable issues
	Gumboro and Newcastle disease important for poultry	Improved disease diagnosis and vaccine production based on biotechnology
	Limited information on active compounds in medicinal plants, but greater awareness of the role of medicinal plants in veterinary medicine	
3. Socio-economics and policy	Self-sufficiency in dairy products in India and Pakistan; deficit in others	Causes of uneven dairy development across AEZ and countries
	Meat consumption low in all countries	Impact of macro-economic and sector policies on incentives for smallholder production and regional trade
	Dairy development uneven across AEZs and countries	Structure of demand for animal products
	Limited knowledge on the linkages between demand for animal products and response of production systems	Impact of various constraints on loss of potential output
	Economic policies have been liberalised in all countries to varying degrees. However, limited regional trade exists with neighbours	Factors influencing improved technology adoption, productivity and dynamics of production systems
	Increasing mechanisation in irrigated areas and decrease in large ruminants in some countries	Structure and efficiency of dairy and feed markets
	Increasing commercialisation of agriculture and rising wage rates in irrigated areas	Impact of policy on resource degradation
	Women play a significant role in animal management	Efficiency of small ruminant markets
	Access to livestock credit limited	Impact of livestock development on food security, poverty alleviation, gender roles, risk management
	Livestock technology transfer process weak	
4. Training and information exchange	Research capacity stronger in India than in other countries	
	Farming systems and multidisciplinary research weak	
	Inadequate contact and information exchange amongst scientists and institutions in the region	
	Library facilities are relatively poor and access to information is especially weak	

There are no researchable issues in training and information exchange. In all countries training is needed in methodologies for farming systems research. In some countries specialised training is needed, e.g. in socio-economics and biotechnology. Networking arrangements are needed to link institutions and scientists. Access to and exchange of information must be improved.

Conclusions

The situational analysis in the target AEZs and the production systems has enabled a sharper focus on the key researchable issues. The analyses re-emphasised that the major technical constraints were feed resource availability and animal health. Several researchable issues in socio-economics and policy were identified, as were training and information needs. Limited resources dictate that all researchable issues cannot be addressed simultaneously. Furthermore, ILRI does not have comparative advantage in every research area. Therefore, prioritisation of researchable issues and the formation of partnerships with other international organisations and NARS will be essential.

6 Strategy for research and recommendations

Justification for research

The strategy for research to improve livestock in crop–animal systems in South Asia builds on the information presented in the previous chapters. The justification for research on crop–animal systems is associated with the following factors:

- There is widespread poverty and concerns about equity and food security. A very high proportion of the human population (49%) currently lives below the poverty line. Furthermore, the percentage of rural poor as a percentage of the total poor is also very high. For India, this figure is about 79%.
- In future, rising populations, higher incomes, urbanisation and changing consumer preferences will fuel an increased demand for animal products.
- In Asia, 51% of the cattle, 74% of the buffalo, and 55% of the small ruminant populations are found in the target AEZs. The productivity of these animals in both the rainfed and irrigated areas needs to be increased to meet future demands for animal proteins, notably milk, beef, goat meat and mutton. For this reason, governments in the region have given priority to the development of ruminant production.
- The arid/semi-arid AEZs are fragile environments that require protection. Common property resources in rainfed areas are declining and land degradation is occurring through overgrazing, erosion and nutrient depletion. Soil salinity is increasing in irrigated areas. Environmental pollution is a problem in peri-urban and urban production systems.

Increased resource allocation for research on crop–animal systems in the target AEZs is clearly necessary in the context of the need for more food, greater equity and also environmental considerations.

Guiding principles

Guiding principles are important for research to improve animal production in crop–animal systems. These principles include:

- a clear definition of priorities within production systems, species and commodities
- research must be problem-solving, have application and fuel development
- research and development programmes should address major constraints, real needs, and generate new knowledge and products. The programmes need to ensure technology delivery to clients, e.g. NARS and farmers, and include training opportunities
- institutional commitment to demand-led research that is multi-disciplinary and systems-oriented
- the comparative advantage for research of individual, public and private sector organisations must be recognised and strong linkages promoted. The development process can also be enhanced significantly by promoting symbiotic relationships with the private sector, extension services, NGOs and community organisations. Active partnerships between NARS and these groups, with ILRI acting as facilitator, can extend impact

- research programmes must acknowledge current concerns on poverty alleviation/elimination, food security, environment, equity, gender and sustainability.

Recommendations on priority production systems and researchable areas

The following priority production systems are identified in this report for future research:

- dairy production systems in rainfed and irrigated mixed farming systems
- goat and sheep production systems linked with annual cropping in the rainfed mixed farming systems.

Dairy production systems are common to all of the six countries. Goat and sheep production systems are important in the semi-arid AEZ of India, Pakistan, Nepal and Sri Lanka.

Dairy production

A considerable amount of component research along disciplinary lines has been conducted with dairy production systems in South Asia. Impressive progress has been made in genetic improvement of cattle through crossbreeding, the development of improved forages for animal feed, the biological and chemical treatment of cereal straws, and animal health interventions. However, much of this work has been conducted on experiment stations and has lacked a farming systems perspective. Component technologies have been validated on farm but seldom adopted. This lack of a farming systems approach has meant that important interactions between nutrition, genotype and disease and between livestock and crop production have been ignored. ILRI can be instrumental in leading multi-disciplinary research with a farming systems perspective on the improvement of dairy production systems in the target AEZ of all six countries. Although the buffalo is not a CGIAR-mandated species, given its importance in the region, it cannot be ignored as a component of the production system. This was further endorsed by the consultation for South-East Asia (Gardiner and Devendra 1995). Dairy development in the humid areas of Bangladesh and Sri Lanka has relevance for the South-East Asia programme.

In every country, a variety of feed resources are available that fluctuate throughout the year. These are predominantly crop residues but, depending on the country and area, include varying quantities of forages of one sort or another, agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR). Research should identify the potential importance of these feed resources at different times of the year, and synchronise availability with the physiological and productive needs of animals. Mathematical modelling techniques can be introduced in this approach. Nutrition and feed resources would be the pivot around which other components of the research programme would rotate. These components include:

- different species (buffalo and cattle) and genotypes (indigenous and crossbred)
- genotype–nutrition interactions can be evaluated along with the effects of diseases and animal health interventions
- nutrient recycling would provide the link between animal production and crop production. The sustainability of major cropping systems in the region is declining due to a decrease in soil organic matter. Nutrient flows can be monitored and existing strategies for more efficient recycling introduced and tested in the cropping patterns (e.g. use of legumes as catch-crops in rice-based systems).

This umbrella proposal encompassing a number of important researchable issues, is truly multi-disciplinary and reflects a farming systems approach to research on dairy production which is novel for the region.

Small ruminant production

Rural small ruminant production has not received the attention provided to large ruminants. Yet, from a poverty focus, small ruminants play a critical role in South Asia in generating income for marginal farmers and the landless, and providing proteins for the poorer echelons of society. Furthermore, there is a strong link between these systems and environmental issues concerning common property resources. Sedentary farmers, who keep goats and sheep, are forced into transhumance in the dry season in a search for feed whilst the landless are almost totally dependent on common property resources for grazing. In consequence, there has been an increase in land degradation from overgrazing and erosion. During the course of these migrations, small ruminants play an important role in the maintenance of soil fertility through folding contracts, i.e. manure for cash or for crop residues. For sedentary arable farmers, it is an effective means of compensation for the depletion of soil nutrients and provides income for the landless. ILRI, with its long experience of small ruminant research in extensive grazing systems in sub-Saharan Africa, can spearhead this research in India, Nepal, Pakistan and Sri Lanka. Initially, emphasis should be on socio-economic and policy issues to focus research on technology interventions.

Existing systems need to be thoroughly characterised and the constraints/opportunities identified for better integration of small ruminants with annual cropping systems in the rainfed areas. Environmental impacts of the traditional systems need to be assessed along with the effects of changes resulting from the introduction of new or available technologies. Finally, there is a strong linkage between these issues and the lack of an organised marketing system for small ruminant products.

Other opportunities

Partnerships between ILRI and NARS will be essential to address the researchable issues identified. Priority setting is needed, and it is clear from the country visits that, throughout the region, this is weak in every research system. ILRI has considerable experience in *ex ante* analysis for this purpose. NGOs can also play a valuable role in this process by defining uptake pathways and diffusing new technology.

ILRI can provide back-stopping in a number of cross-cutting methodologies. For example, the need to characterise indigenous breeds was highlighted in every country. Concerns about genetic erosion, resulting from crossbreeding, were expressed and ILRI can transfer its experience in modern biotechnology (e.g. the use of genetic markers) to the region. The use of such biotechnology in disease diagnosis and vaccine development, and the experience with tick-borne diseases are other areas of opportunity. Tick-borne diseases are increasing in importance in a number of countries with the development of crossbreds based on temperate breeds. ILRI can also provide expertise in socio-economics and policy research, e.g. marketing issues.

Finally, ILRI can play a valuable role in strengthening NARS capacity. Training in farming systems research and in specific laboratory techniques in molecular biology are two areas of priority. Information exchange can be improved in all of the countries, and networking promoted as a means of bringing together scientists from the region. Ultimately, networking can foster linkages with South-East Asia.

Resource requirements

There should be a minimum of five international scientists based in the region as follows:

- dairy production: one feed resources specialist (with modelling expertise) and one natural resource management specialist (with expertise in nutrient recycling)
- small ruminant production: one feed resources specialist, one natural resource management specialist (with expertise in common property resource use), and a socio-economist (with experience in systems analysis). The socio-economist will have inputs into the dairy production projects.

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Appendix I

Animal agriculture in the six countries

Bangladesh

Environment and cropping systems

Bangladesh is a low-lying riverine country found between latitudes 20°N and 26°N, and contains a wide range of environmental conditions—30 agro-ecological zones (AEZs) and 88 sub-regions have been delineated (UNDP–FAO 1988). The country consists of a number of flat alluvial flood plains of extensive river systems such as the Brahmaputra and the Ganges running north to south in the western, central and eastern parts; two uplifted blocks in the west and centre (the Barind and Madhupur Tracts); and the hill country in the north and east.

In Bangladesh, temperatures are suitable for crop cultivation throughout the year, so the length of the growing period is determined mainly by soil moisture supplied from rainfall and flooding. Irrigation may be used to supplement these sources and artificially extend the duration of crop growth. Rainfall ranges annually from 1500 mm in the west to 5500 mm in the east. During the monsoon months, the excess of rainfall over potential evapo-transpiration ranges from 750 mm in the west to 4000 mm in the east. The cool dry winter growing period (*Rabi*) extends from October to March, the hot humid pre-summer growing period from March to May, and the summer (*Kharif*) growing period from May onwards.

Twenty-one soil types are described in detail by UNDP–FAO (1988). They are simply differentiated into three physiographic groups: flood plain soils (80% of the land area), hill soils (12%) and terrace soils (8%). The soils are universally deficient in nitrogen and zinc, and organic matter levels are low (<1.5%). The declining fertility of soils in the country is the result of depletion of organic matter caused by high cropping intensities (BARC 1997). Both inorganic and organic fertilisers are used in Bangladesh. Inorganic fertilisers were first introduced into the country in the early 1950s, but expansion only took place in the 1960s with the introduction of modern crop varieties and the increased development of irrigation systems. Fertiliser use continues to increase, with nitrogen (N) constituting 80% of all nutrients applied. Positive responses to fertilisers have been demonstrated in experiments over the last 30 years and, in general, depending on climate–soil–crop conditions good responses to N, phosphorus (P), potassium (K), sulphur (S) and zinc (Zn) have been noted. In 1995–96, the total inorganic fertiliser used was 108 kg/ha per year, more than that used in India or Pakistan. Overall, inorganic fertilisers are responsible for 50% of total crop production. However, increases in the yields of major crops resulting from artificial fertilisers may vary and range from 17% for mungbean to 65% for mustard.

Although inorganic fertilisers can supply high concentrations of limiting plant nutrients, it is the organic fertilisers that replenish organic matter in the soil and are responsible for improving physical properties. In Bangladesh, manure and compost made from plant and animal wastes are applied widely. There is also increasing interest in green manure crops experimentally and in farming practice. The summer season is more favourable for growing green manure crops as the rainfall and high temperatures encourage rapid growth (50–55 days) and decomposition when they are incorporated into the soil. Depending on species and environmental conditions, green manure crops can add between 60 and 120 kg N/ha to the soil. Farmers are being encouraged in Bangladesh to grow a green manure crop once every three years. The On-Farm Soil Fertility Management Project, financed by the Danish and Bangladesh Governments at the Bangladesh Agricultural Research

Institute (BARI), is addressing issues such as the role of green manure crops in different cropping systems, the use of organic/inorganic/bio-fertilisers and integrated fertiliser management (Haq and Islam 1997).

Problem soils occur in various AEZs. Coastal saline soils occupy 1.5 million hectares and are characterised by high salinity in the dry season (October – May), low organic matter, nutrient deficiencies (N, Zn, copper (Cu) and manganese (Mn)) and ionic imbalances. Such soils are largely single cropped, with fallow–rice–fallow being the predominant cropping pattern. Acid sulphate soils are affected by flooding and tidal bores, and the areas are prone to cyclonic activity. Phosphorus is deficient in these soils and iron toxicity may be a problem for wetland rice grown when tidal flooding is prevented by embankments. Peat soils, occupying 0.13 million hectares, are characterised by deep flooding in the wet season, wetness throughout the dry season, sulphur toxicity and low availability of nutrients (K, Zn and Cu). Some peat soils can be used for wetland rice growing. Hill soils on sloping land are very vulnerable to erosion and are best left under perennial crops and permanent grassland. In waterlogged soils, microbial activity is hampered, nutrient availability (S and Zn) reduced, and the formation of methane and hydrogen sulphide promoted.

Land is used intensively. About 34% of the arable land is single cropped, 40% double cropped, 10% triple cropped and 16% remains under fallow or as wasteland. Innumerable cropping patterns are found in Bangladesh depending on agro-ecological conditions and the availability of irrigation facilities. These are predominantly rice-based systems, since rice is the pivotal crop around which many other crops such as wheat, jute, potato, oilseeds and pulses rotate. In the north-west of the country, maize is increasing in importance as a dual-propose crop for human consumption and for use in commercial poultry rations. Sugar-cane and tea are also important perennial crops. In the past, pulses were used partly as green fodder but the land under pulses has declined rapidly with the expansion of irrigated agriculture. The negative consequences of irrigated agriculture on the livestock and fisheries sub-sectors have been demonstrated, and the need for a systems approach to research has been argued by some authors (Jabbar and Green 1983; Jabbar 1985). However, it has taken many years for these ideas to be of interest.

No forage crops are included in cropping systems at present, but research is being conducted to investigate the inclusion of annual legumes in rice-based systems and the association of maize with multi-purpose trees such as *Leucaena leucocephala*. New interest is picking up to introduce pulse crops into cropping patterns. An extensive list of cropping patterns, for both irrigated and rainfed conditions, is given by the BARC (1997) for each zone. Some examples of these cropping systems are presented in Table A1. These have implications for animal feed supply.

Animal genetic resources

The livestock resources include cattle, buffalo, goats, sheep, chickens and ducks. An important distinguishing feature of the livestock resources in Bangladesh is the very high density—145 large ruminants/km^2 compared with only 9/km^2 in India. Current statistics (1996–97) indicate populations of about 24 million cattle, 9 million buffalo, 35 million goats, 1 million sheep, 153 million chickens and 14 million ducks.

The indigenous cattle are relativly small to those in India and Pakistan and, given the emphasis on improving milk production, crossbreeding with the Holstein–Friesian and Sahiwal has been in progress. The optimum level of exotic blood that is being advocated is 50%, and the effort is being supported by research on frozen semen technology, open-nucleus breeding systems and reproductive biotechnology. Hariana cattle have been introduced from India for crossbreeding for draft purposes.

Amongst small ruminants, goats are more numerous than sheep. Goats are distributed widely in the northern and central regions. The Black Bengal is the outstanding breed for meat and skin production, and is also characterised by high prolificacy. The species is associated closely with resource-poor farmers, providing them with animal protein and food security. To meet the very high demand for goat meat, young bucks are castrated and this is having a negative impact on the breeding strategy for the species. Sheep are less important and are kept for mutton and coarse wool. Attempts have been made to improve wool production by crossing with the Merino.

Table A1. *Some examples of cropping systems in Bangladesh.*

	Rainfed			Irrigated		
Regions	R	K1	K2	R	K1	K2
Flood plains	Fallow	Rice	Fallow	Rice	Rice	Rice
	Potato	Sesame	Rice	Rice	Fallow	Rice
	Vegetables	Rice	Blackgram	Wheat	Rice	Rice
	Mustard	Fallow	Rice	Potato	Rice	Rice
	Mungbean	Rice	Rice	Wheat	Jute	Rice
	Chick-pea/	Rice/Jute	Rice	Vegetables	Rice	Rice
	Grasspea	Rice/Jute	Fallow	Tobacco	Jute/rice	Fallow
	Onion/garlic	Rice	Fallow	Potato	Jute	Rice
	Sweet potato	Jute	Rice	Blackgram	Rice	Fallow
	Vegetables	Rice	Rice	Vegetables	Jute	Fallow
	Wheat					
Hills	Cowpea	Rice	Rice	Vegetables	Fallow	Rice
	Sweet potato	Fallow	Rice	Rice	Fallow	Rice
	Fallow	Fallow	Rice	Vegetables	Vegetables	Fallow
	Rice+maize	Fallow	Rice+okra+ cotton	Gourds	Rice	Rice
Barind/	Mustard	Rice	Fallow	Wheat	Fallow	Rice
Madhupur	Chick-pea	Fallow	Rice	Potato	Fallow	Rice
Tracts	Vegetables	Rice	Fallow	Rice	Fallow	Rice
	Fallow	Rice	Rice	Mustard	Fallow	Rice

R= Rabi; K1 = Pre-Kharif; K2 = Kharif.
Source: BARC (1997).

Backyard poultry production is very common in the rural areas, and is an important source of animal protein as well as cash income. Commercial poultry production is mainly in the hands of the private sector, and is based on imported technology including the use of hybrid birds, vaccination and mixed concentrate rations.

Many of the indigenous cattle and buffalo remain 'nondescript'. This is also true of sheep. However, the Black Bengal goat has been reasonably well characterised. Policy concerning the improvement of indigenous breeds appears unclear. In the absence of programmes that specifically focus on within-breed selection and improvement of indigenous breeds, indiscriminate crossbreeding has taken place which is seriously eroding the genetic base and productivity.

Animal production systems

Integrated crop–animal systems are the dominant type in the country and mainly involve farmers who keep small numbers of animals (3–6 head/household). Cattle, goats and native chickens are often reared together for multiple uses. Given the large reserves of surface water and the dominance of rice production, animal production systems resemble those in the Mekong countries of South-East Asia. Two main types of crop–animal systems are recognised—those involving mainly cattle and goats in the drier arable areas, and those with more surface water where fish are also integrated into the system. A survey in 10 Thanas (administrative units) in 8 districts indicated that 70% of the farmers were involved in crop–livestock–homegarden–agroforestry systems, 19% in crop–livestock–homegarden–fish systems, and the remainder were involved with fewer components in the systems (Ministry of Agriculture 1994).

Dairy production from cattle is particularly important and is encouraged to meet increasing domestic demand. Milk is collected from peri-urban areas such as Baghabarighat in the Dhaka milkshed, where feeds are available and crossbred cattle (average yields of 750 litres/lactation) are kept. Peri-urban milk production and marketing is well organised around Dhaka. While demand promotes dairy production in the peri-urban areas, milk production in other parts of the country is less well-organised because of marketing constraints. The Bangladesh Milk Producers Co-operative Union Limited is the oldest dairy venture in the country providing feeds, vaccines and artificial insemination for the 40,000 participants.

Feed resources

Low livestock production in Bangladesh is due mainly to a deficiency in the availability of feed resources and to the poor nutritive value of many of these feedstuffs. The main feeds available to ruminants are crop residues, agro-industrial by-products (AIBP), leaves from trees, and native grasses from roadside verges, paddy bunds and fallows (Islam and Ahmed 1992). However, information on feed production and utilisation is relatively scarce. With 84% of the total land area used for cereal cultivation, mainly rice, it is not surprising that rice straw and bran contribute 90% of the energy available for ruminants. Other straws are derived from wheat and pulses. However, only 40% of straw production is used for ruminant feed. The remainder is accounted for by alternative uses such as fuel and compost, and losses in storage during the wet season. High human population pressures and an increase in cropping intensities have led to a progressive and drastic reduction in the native grazing lands. Other sources of roughage include sugar-cane tops, wastes from fruit and vegetables, and non-conventional feed resources (NCFR) such as aquatic plants (water hyacinth and duckweed). Concentrates available in Bangladesh include brans (rice, wheat and pulses), cereal grains, oilseed cakes, molasses, fishmeal and raw shrimp waste (4000–5000 t annually). However, only 7% of thedry-matter consumed by ruminants comes from concentrates. There is strong competition from the increasing commercial poultry sector for concentrate feeds. Very little grain, other than broken rice, is fed to ruminants. Some rice bran is fed to dairy cows and draft animals, but other concentrates are too expensive.

Given the importance of rice straw, much research has been conducted on ways of improving its nutritive value by supplementation or treatment with ammonia and urea (Islam and Ahmed 1992; Saadullah 1992; Kibria 1994). Traditionally, straw is chopped and soaked in water before feeding, but intake is poor and digestibility and crude protein (CP) content are low. Untreated straw will not provide a maintenance diet for large ruminants. Although significant improvements in nutritive value have been achieved with urea treatment, this has not always been a sustainable system at farm level even if adopted. Surveys in Bangladesh have confirmed the interest of farmers in many districts, but there is often insufficient straw available throughout the year for treatment. The increasing use of high yielding short-strawed varieties is contributing to the roughage deficit. Urea has also been incorporated into blocks with molasses as a ruminant feed, but this technology is not used widely in the country.

Various strategies have been suggested to reduce the ruminant feed deficit. These include measures to reduce crop residue losses in storage; the establishment of multi-purpose leguminous trees such as *Leuceana leucocephala* in plantations and herbaceous legumes in orchards to supplement rice straw; inter-cropping or relay cropping rice with annual legumes such as grasspea (*Lathyrus sativa*) or cowpea (*Vigna unguiculata*) at the end of the summer season; and the use of NCFR such as duckweed and leather shavings. Duckweed can produce annual dry-matter yields of 10–30 t/ha with a CP content of up to 43% and a dry-matter digestibility of >75%. A diet of crop residues and fresh duckweed can provide a balance of nutrients capable of optimising rumen fermentation capacity. Duckweed can also be fed to chickens and ducks. Leather shavings, a waste product from tanneries, can be fed to growing cattle or broilers to replace fishmeal. After soaking and boiling in water, the CP content of the leather shavings is increased to 84%.

Animal health

The major infectious diseases which cause significant losses in cattle and buffalo in Bangladesh are foot-and-mouth, rabies, contagious bovine pleuropneumonia, haemorrhagic septicaemia, anthrax, black quarter, bovine tuberculosis, brucellosis, calf scour and calf diptheria. In sheep and goats, the important diseases are sheep/goat pox, enterotoxaemia and anthrax. In poultry, Newcastle disease, fowl pox, fowl/duck plague, fowl cholera, Marek's disease, infectious bursal disease (Gumboro), leucosis complex (lymphoid leucosis), fowl typhoid and pullorum disease are important.

In addition to the infectious diseases, parasitic diseases are widespread in the country. The most harmful parasites of ruminants are nematodes, flukes and cestodes. Ectoparasites are encountered in ruminants and poultry. Amongst the protozoal diseases, babesiosis, theileriosis and trypanosomiasis are common amongst ruminants whilst coccidiosis poses a serious threat to the poultry industry.

Limited information is available on the incidence and epidemiology of these diseases. Although accurate data are not available on the economics, the Department of Livestock Services (DLS) has made some estimates of the costs of diseases in Bangladesh. Foot-and-mouth disease outbreaks with stereotypes OAC and Asia-I occur at least twice every year, usually in April/May and November/December. In every outbreak around 50% of the ruminants are affected and the annual economic loss is estimated at US$ 125 million. Peste des petits ruminants (PPR) made its first appearance in epidemic proportion in 1996 and affected 100% of the goats in 75% of the districts, causing mortalities of up to 90%. The disease now persists in endemic form. Similarly, an outbreak of goat pox first occurred in 1984 in western districts of the country resulting in severe economic losses to the goat industry. The disease now exists in the country in endemic form, and annual loss from this disease is estimated at US$ 0.75 million. Anthrax, black quarter and haemorrhagic septicaemia outbreaks occur sporadically resulting in a 40% loss in cattle. Annual loss from these diseases for 1996 was estimated at US$ 2.3 million.

Calf scour and calf diptheria are the two most harmful diseases of calves and can cause death in up to 50% of affected animals on farm. Bovine tuberculosis has been recorded in 15% of cattle under farm conditions and is considered a serious threat to public health. Brucellosis, causing abortion and retention of the placenta, has been recorded in 50% of the local cows and in 26% of crossbred cows (BLRI 1988). Amongst the infectious diseases of poultry, Newcastle disease is under control whereas frequent outbreaks of fowl cholera, fowl pox and pullorum disease are reported with resultant losses of up to 30% of the flocks. Gumboro has emerged recently in the country through imported chicks and caused severe losses from 1992–96. At present it is being controlled using imported vaccines.

The incidence of parasitic diseases is usually very high and ranges from 30–80% in ruminants. Young crossbred animals are severely affected (Rahman 1988). Losses arise from deaths (10–15%) of young animals, stunted growth, reduced milk and meat production and draft output, delayed maturity and prolonged calving intervals.

Disease control activities are carried out and monitored mostly by DLS. They consist of disease diagnosis, treatment and surveillance, quarantine and vaccine production. Diagnosis is carried out primarily in the 464 Thana Livestock Development Centres (TLDC) with necessary confirmatory diagnosis performed in the one central and eight regional diagnostic laboratories, which are well-equipped. Treatment of infected animals/birds is carried out mostly in the TLDC and around 40 animals/birds are attended to daily in each of the 464 TLDC.

Priority areas for animal health activities include the identification of the important disease problems affecting livestock at both the national and farm levels, and the development of interdisciplinary research programmes to solve these problems.

Future research on cattle should strengthen facilities for foot-and-mouth disease virus identification and create facilities for reference virus strains, antigens, antisera, diagnostic reagents, and typing/subtyping of the virus. Epidemiological studies on economically important infectious and parasitic diseases should be carried out so that endemic areas can be mapped and control models developed. Factors that cause sterility and infertility in cows and artificial insemination problems also need to be studied. Medicinal plants that can be used to formulate cheap and effective drugs to treat cattle diseases should be identified.

Future research on goats should identify and quantify the effects of diseases including those caused by parasites. Epidemiological studies on the economically important diseases should be undertaken, and control methods developed. Effective vaccines against PPR and goat pox should be developed through regional collaboration.

Other issues of importance are to evolve simple and easy sero-diagnostic techniques for detection of infectious diseases; to develop effective disease reporting and monitoring systems for surveillance of notifiable diseases; to develop models for strengthening research and extension linkages for the appropriate identification and prioritisation of disease problems; to establish regional/international collaboration for the creation of buffer zones against highly infectious diseases; and to train young scientists in the design of multi-disciplinary research projects.

Socio-economics and policy

Livestock contribute 3% to the gross domestic product (GDP) of Bangladesh and 9% to the agricultural GDP. The contribution to the agricultural GDP increases to 14% if the value of traction and manure is included in the computation. Livestock perform many economic, social and environmental functions in the mixed farming systems in the country. However, crops, particularly rice and wheat, have received priority in development and research plans because of the need to produce grain to feed the rapidly increasing human population. Grain crops, especially rice, are a highly-politicised crop in the country whose prices may determine the success or failure of parties in the government. Nevertheless, from the mid-1980s, importance has been shifting to the livestock subsector. In the Fourth (1992–97) and Fifth (1997–2002) Five Year Plans poverty alleviation, improved nutrition and employment generation (particularly for the landless and women) have been specified as objectives for the development of the livestock subsector.

Some of the important features of recent government policies towards the livestock subsector are: the non-involvement of government in production, processing and marketing activities; the support of the private sector and non-governmental organisations (NGOs) in these activities through research, extension, training, credit and the development of appropriate infrastructure; the reduction, and in time, elimination of subsidies on inputs including veterinary drugs and services; and the reduction of import tariffs on equipment, raw materials and other inputs that will contribute to the development of the subsector. Already, some of these provisions have produced positive results.

Draft animals are the principal source of power for intensive land preparation. However, land scarcity is so high that many smallholders cannot afford to maintain draft animals due to a shortage of feed. Draft power shortages have been shown to adversely affect crop production (Jabbar and Green 1983; Alam 1995). In the 1960s and 1970s, mechanical power was found to be economical if heavy subsidies were provided. In recent years, reduced import tariffs on agricultural equipment and rising costs of animals and feeds have made mechanical power, particularly small power tillers, highly competitive with animal power. Consequently, the share of mechanical power increased from around 5% in the mid-1980s to 15–20% at present. Some rich farmers purchase power tillers for hiring to smallholders who do not own draft animals. This trend is likely to continue although it will be a long time before animal power is reduced to an insignificant level.

In the mid-1980s, the importation of powdered milk cost about Toka (TK) 4500 million (US$ 113 million) annually. This has now been reduced to about TK 2500 million (US$ 57 million) due to a dairy development programme that provides soft loans to establish dairy farms and import exotic cattle breeds. A milk producers co-operative and an NGO are providing milk marketing and processing outlets to these dairy enterprises.

The Grameen Bank, a famous credit institution, has provided about 50% of its loans and about 25% of its loan fund to the landless and smallholders, principally women, for livestock-related activities. Dairy cattle, beef fattening and goat and poultry rearing are included. The Bangladesh Rural Advancement Committee (BRAC) and Proshika, two other large NGOs in the country, also have very large livestock development projects targetting landless and marginal farmers, particularly women, as part of their rural development and income-generation activities. These are implemented in collaboration with the DLS. Technical support, input supply, credit and training are essential components of these programmes. The programme of BRAC (Huq and Sabri 1992) includes poultry development (vaccination by trained vaccinators and support to small-scale chick and poultry rearers, hatchery managers and feed traders) and cattle development (training of para-veterinarians for rural vaccination, supply of local and crossbred dairy cattle, beef and goat fattening, artificial insemination, supply of concentrate feeds and the introduction of fodder). With support from the Asian Development Bank (ADB), the feasibility of charging farmers for vaccination and veterinary drugs has been tested in a pilot area and further evaluation is underway.

Although the positive effects of recent livestock development policies are encouraging, both policy formulation and its implementation needs to be supported by much more appropriate socio-economics and policy research. Consequently, it is not known if appropriate policy instruments are being used to attain stated objectives; if public, private and NGO resources are directed at socially optimal activities; or if resources are used efficiently. For example, liberal economic policies have made mechanical power economical but it is not known what happens to the livestock population dynamics in areas where mechanisation is spreading rapidly. Are dairy cattle replacing draft cattle? If so, what kind of support is needed to encourage dairy development in a more efficient manner? What are the consequences for manure production? The dairy development programme has registered some short-term successes but at what cost? Apparently, dairy farms have been established in highly dispersed areas and market access has become a problem. As a consequence, there are reports of some dairy farmers liquidating their business ventures. This programme also started without a national breed development policy and without taking into account the feed deficit problem in the country. The only milk producers' co-operative in the country operates in limited areas, so it is incapable of providing feed, marketing and healthcare services to dispersed dairy farmers. Adequacy, efficiency and impact of NGO-led livestock development and credit programmes are not known. Given their large sizes, improved efficiency will add to social welfare. The scheme to privatise vaccine production and delivery services need to be assessed properly before large-scale implementation.

Socio-economics and policy research on several issues are required to make these programmes more effective and help chart new directions. Unfortunately, interest and support for socio-economics and policy research related to livestock is poor. For example, the Agricultural Economics and Rural Sociology Division of BARC supported 60 small and large projects between 1981 and 1996. However, only two of them were on livestock. The Faculty of Agricultural Economics and Rural Sociology at the Bangladesh Agricultural University (BAU), Mymensingh, has produced about 500 MSc theses in the last 25 years. Again, not more than 10 of them dealt with livestock. Only after the establishment of the Bangladesh Livestock Research Institute (BLRI) did micro-economic research on livestock accelerate.

The Agricultural Economics and Marketing Division and the Farming Systems Research Division of BLRI have undertaken a number of interesting micro-economic studies during the past 10 years, including a review of the draft power situation and livestock credit; the effectiveness of artificial insemination and the crossbreeding programme; and the economics of improved feeding. However, the quality and usefulness of these studies could have been improved significantly if the researchers had received improved orientation in social science, systems analysis and statistical methods, and had access to improved statistical software and computers. More co-ordination amongst agricultural economics and farming systems research divisions and contact with biological scientists in the choice of topics and design of experiments/surveys would also have contributed significantly to the improvement in quality of those studies. The BLRI economists did not undertake sector and macro-level policy analysis perhaps because of lack of support and capacity. The BAU, other universities, and the Bangladesh Institute of Development Studies (an autonomous organisation attached to the Planning Ministry) should be encouraged and supported to undertake these studies.

Institutions

Agriculture is currently handled by three ministries—the Ministry of Agriculture and Food (for crops), the Ministry of Fisheries and Livestock, and the Ministry of Forestry and the Environment. Each ministry controls its affiliated research institutions which are organised mainly along commodity lines, e.g. rice, jute, sugar-cane, cotton, fisheries and livestock. The NARS consists of the BARC as the apex body and its affiliated research institutions under the three ministries mentioned above. University education and research is co-ordinated by the University Grants Commission, an autonomous body under the Ministry of Education. BARC provides some funds to the universities for specific research projects under contractual arrangements.

Until 1995, BARC was primarily a co-ordinating body with practically no executive control over the programmes and budgets of its affiliated institutions. A new Act of Parliament has provided the institute with programmatic and budgetary powers over its affiliated institutions. Annual research programmes and budgets are vetted by BARC before approval by the concerned ministry. BARC also plays a significant role in the appointment and promotion of senior staff of affiliated institutions, based on predefined multiple criteria rather than seniority as was the earlier practice.

Until the establishment of BLRI in 1984, livestock research was conducted by DLS and by BAU. Research at DLS focused primarily on supporting vaccine production for various diseases, poultry production, and on a crossbreeding programme for dairy development. The research had little impact on the livestock subsector, as little had actually been done to generate appropriate technologies except for the poultry subsector. The crossbreeding programme was pursued without any systematic plan or objective.

The Faculties of Animal Husbandry and Veterinary Sciences, BAU, produce separate graduates in production and health, although each group takes some minor courses from the other. Having failed to convince BAU of the need of clients (DLS, NGO and the private sector) for broad-based combined production and health graduates, the Ministry of Fisheries and Livestock decided recently to establish three new veterinary colleges to produce such graduates. The principal mode of research in BAU is through MSc and PhD programmes. In some cases, staff undertake specific project-based research funded by BARC, the University Grants Commission or external donors. Since BAU does not have a mandate for extension, and there is no linkage with DLS for delivery of technologies, its research programme has no long-term vision on the needs of the country, and rarely are research results packaged for delivery to end users. In addition, multi-disciplinary research is not common at BAU. A Farming Systems and Environmental Studies Project has been in operation at a small field site for several years, and this has provided opportunities for some scientists to participate in a multi-disciplinary mode. Another project, currently being implemented with UK funding to integrate forages into rice-based cropping systems, is also multi-disciplinary. Recently, some BAU and BLRI staff took up joint projects, on personal initiative, which have better prospects of being multi-disciplinary and of service to farmers.

Recently BARC prepared a National Master Plan for Agricultural Research with assistance from the International Service for National Agricultural Research (ISNAR), The Netherlands. Using scoring and economic surplus methods, priority research areas were identified. Livestock research is receiving higher priority than at any time in the past. Animal health, feeds and nutrition, breed improvement and supporting socio-economics and policy research are being emphasised as is livestock systems research, within the context of general farming systems research. Currently, the priority areas for research are being supported under a United States Agency for International Development (USAID)-funded Agricultural Research Management Project (ARMP) co-ordinated by BARC.

The approach to research has been commodity-oriented and highly discipline-related across institutions. The Bangladesh Rice Research Institute (BRRI) started rice-based cropping systems research in the mid-1970s by establishing a Cropping Systems Research Division. In the mid-1980s, this was changed to a Rice-Based Farming Systems Research Division though the primary emphasis remained on incorporating rice-related component technologies into the farming systems. Bangladesh Agricultural Research Institute (BARI) has had an On-farm Research Division (OFRD) from its inception to undertake on-farm validation tests of BARI-generated technologies. Later, OFRD was also mandated to undertake farming systems research, but its focus remained on various component technologies for its mandate crops (roots, tubers, pulses, oilseeds and horticulture). Other institutions also started farming systems research projects and BARC launched a programme to co-ordinate these activities across national institutions. BLRI established a Farming Systems Research Division at its inception. Until 1996, these farming systems activities suffered from two main deficiencies. First, the research teams or projects were multi-disciplinary but the parent institutions were highly discipline oriented. Consequently, the projects were not able to influence the research agenda and output of the institutions. Second, all projects in crop institutions focused on cropping patterns and crop technologies. Although initial site descriptions included information on livestock and their role, interactions amongst various components of the system were not addressed or quantified in experimental work.

Under the new USAID-funded ARMP, a serious attempt is being made to follow a systems approach in all 16 farming systems research sites managed by various institutions. The sites are being managed by multi-disciplinary teams of scientists drawn from collaborating institutions. It is hoped that various components of the farming system will now receive a balanced treatment at the FSR sites, and that interactions amongst components will be addressed in systems descriptions and experiments to improve those systems.

Bhutan

Environment and cropping systems

Bhutan is a small and extremely mountainous country found between latitudes 27°N and 29°N, covering an area of 46,500 km^2 between China (Tibet) and the Assam Plain of India. The population is estimated to be 680,000 people of whom 90% live in isolated rural communities. Some 8% of the total land area is under cultivation with 45% of the farmers cultivating <1.0 ha (16% of the cultivated area) and some 16% cultivating >2.5 ha (42% of the cultivated area). Agricultural activities are concentrated along the river valleys in the central belt of the country and in the foothills of the south. In these areas farmers practice integrated agriculture with crops, livestock and forestry. About 28,000 ha of land are used for rice cultivation on terraces. Forests occupy 64% of the surface area of Bhutan, and are more or less evenly distributed regionally. Most forests in the north contain conifers, pines and firs whilst, in the south, broad-leaved and mixed forests predominate.

Bhutan has an extremely diverse agroclimate due to major differences in altitude, rainfall, slope and soils. There are four physiographic regions, viz. the Southern Foothills, the Middle Mountains, the High Mountains and the Himalayas which rise to 7700 m above sea level. Climatic conditions range from hot and humid subtropical conditions in the south to the ice and glacial conditions in the Himalayas in the north. Six agro-ecological zones (AEZs), based on rainfall and temperature, have been identified. These are Alpine, Cool Temperate, Warm Temperate, Dry Subtropical, Humid Subtropical and Wet Subtropical (Table A2). In all of these zones, livestock provide draft power, manure for fertiliser and fuel, and various animal products. In the Alpine zone no crops are grown and transhumant livestock production, based on the yak, is practised. Livestock (cattle, sheep and horses) again predominate in the sub-Alpine zone. In the remaining four zones, mixed farming is common. Rice-based cropping systems are found in the western and southern districts (warm temperate and subtropical), maize-based cropping systems in the eastern districts (warm temperate and subtropical), whilst buckwheat is the major grain crop in the northern districts (cool temperate). Wheat, vegetables and oilseeds are also important crops in the country, oranges, apples, potato, ginger, cardamom, coconut, chilli and lemons are amongst the main cash crops. In the cropping areas the main livestock are cattle, mithun, buffalo, sheep, horses and non-ruminants. Some goats are kept in confinement.

Table A2. *Description of the six agro-ecological zones.*

Agro-ecological zones	Altitude (m)	Temperature (°C) Monthly maximum	Temperature (°C) Monthly minimum	Rainfall (mm)
Alpine	3600–4600 (high)	12	-1	<650
Cool temperate	2600–3600 (high)	22	0	650–850
Warm temperate	1800–2600 (high)	26	0	650–850
Dry subtropical	1200–1800 (mid)	29	3	850–1200
Humid subtropical	600–1200 (mid)	33	5	1200–2500
Wet subtropical	150–600 (low)	35	12	2500–5500

Source: Anon (1995).

Five 'production systems' are identified, viz. the Dryland, the Plantation and Orchard, the Wetland, the Pastoral, and the Forest. About 25% of the total contribution of crops, livestock and forestry to the GDP comes from the Wetland Production System. Rice-based systems predominate, viz. Rice–wheat, rice–rice, rice–oilseeds, rice–maize and rice–vegetables. Crop rotations are linked closely with livestock and forestry resources. Manure and organic composts are the main nutrient sources for crops. There is little inorganic fertiliser use and only about 1000 t of fertilisers are imported into Bhutan annually, corresponding to an application of 7 kg/ha of arable land. The scarcity of cultivable land has led to the use of steep slopes for cropping, resulting in increased soil erosion and environmental damage. Erosion also occurs in the overgrazed Alpine pastures.

Approximately 40% of wetland-dominated production systems occur in the mid-altitude Dry and Humid Subtropical zone; about 40% in the low-altitude Wet Subtropical zone; and 20% in the high altitude Warm Temperate zone. In the Wet Subtropical zone, lowland rice is the dominant crop whilst in the other zones irrigated rice is the most prevalent crop followed by various winter crops. In the eastern valleys, the rice-fallow system is predominant. Most wetland areas have irrigation facilities fed by the monsoon rains.

Various forms of shifting cultivation are practised in Bhutan, often in rainfed areas (*Tsheri* lands) originally under forest, and mostly on slopes too steep for cultivation with draft power. One or two rainfed crops are grown and the land is then left fallow for 4-12 years. The government has tried to eliminate or reduce shifting cultivation by using the land for other purposes, including forestry on the steepest slopes. However, evidence suggests that, because of hand cultivation, soil erosion on steep land under this system might be less than on unterraced crop areas, more frequently cultivated by annual ploughing. There is also concern over erosion resulting from overgrazing in forest areas due to increases in the population of cattle. Efforts to rationalise the management of pastures and to control the animals using them have not yet been successful.

During the Seventh Five-Year Development Plan (1992-96), the main objective was to ensure environmental conservation, and the integrated development of crop, livestock and forestry systems within the framework of watershed management. The Eighth Five-Year Development Plan (1997-2002) further emphasises the integrated systems approach within the complex of renewable natural resources, production systems, and socio-economic, cultural and ecological elements.

Animal genetic resources

The animal genetic resources include cattle, buffalo, yak, mithun, goats, sheep, pigs and poultry. Sizeable numbers of horses, mules and donkeys are also present. National data from the Land Use Planning Project indicate that, in 1995, there were about 305,000 cattle, 30,000 yak, 26,000 sheep, 130,000 chickens and 44,000 pigs. There are only 191 mithun in Bhutan but some 65,000 mithun-cattle crossbreds. Buffalo numbers are small. Livestock numbers range between 2 and 8 head per household, with the highest number being found in the temperate regions.

Cattle are mainly concentrated in the east-central, western and west-central regions, where the average number kept is about 3-5 animals per household. The central districts of Wangdue-Phodrang, Trongsa, Bumthang and Zhengang, and western districts of Paro, Thimpu, Punakha and Dagana have the highest concentrations with ownership of four to six cattle. The Siri, a stabilised indigenous draft/dairy type of crossbred origin, has been crossed with the Jersey for milk production and with the Brown Swiss for milk and draft. The recommendation for crossbreeding is the maintenance of the exotic blood level at 50% in the villages. Jersey crossbreds currently account for about 7.5% of the total cattle population. In addition, Red Sindhi, Hariana and Australian Milking Zebu cattle have been introduced into the country.

The mithun is found extensively in Bhutan, and has been crossed with cattle for draft purposes. Breeding stock are imported annually from northern India at a high cost. Yaks are concentrated in the northern districts of Gasa, Ha and Thimpu, as well as in Paro, Wangdue-Phodrang and Bumthang. The average number kept is 3-6 head per household. Yak-cattle crosses are found mainly in the mid-altitude Dry Sub-Tropical Zone.

Sheep have been crossed with the Merino for wool production. Goats are numerically less important but, with sheep, are used for meat production. Sheep are concentrated in Bumthang, Trongsa and Wangdue-Phodrang, and goats in the southern belt of Tsirang, Soulse, Chukha, Dagang and Sarpang. The average ownership of these animals is 3 head per household.

Non-ruminants are increasing in importance. To increase the size and performance of indigenous pigs the Saddleback, Large White, Large Black and Duroc-Jersey breeds have been introduced into the country. Pigs are concentrated mainly in the western districts of Wangdue-Phodrang, where rice is cultivated, and in the eastern districts of Zhengang and Mongar. The average number of pigs kept per household is one to two.

Animal production systems

Two broad types of animal production systems are identified in Bhutan. Extensive grazing systems (cattle, yak and sheep) in Alpine areas where sedentary smallholder and transhumant pastoral systems are dominant. Alpine pastures are grazed during the summer and animals are moved to the lowland areas for winter grazing. In addition, forest reserves are used widely by grazing animals. In the eastern and central regions, there exists about 1.9 ha of grazing land per head of large ruminant. Integrated systems involving mainly cattle, mithun, pigs and poultry are found in the subtropical zones, where rice cultivation is common. In these systems the animals benefit from the limited grazing of fallow land as well as crop residues from rice. There are two important aspects concerning the role of cattle in integrated systems. First, cattle provide draft power for arable crop production. The presence of about 375,000 ha of arable land will require about 25,000 pairs of oxen for a ploughing season of not more than 45 days, with a value estimated at US$ 6.5–7.8 million. Given the limited use of mechanical power and the high cost of its use for crop cultivation, the draft power needs of the country in the lowland AEZs are enormous. The enormous draft power needs emphasise the need for adequate numbers of good quality animals which can contribute to this demand. Second, cattle make valuable contributions to manure product for crop cultivation.

Feed resources

The emphasis on extensive pastoral production systems underlines the importance of pastures in the systems. Much effort has been directed over the last three decades to forage introduction, evaluation, selection and seed production. Early introductions involved Kikuyu grass, Napier grass and white clover. The precise impact of these efforts is not clear, but it has been reported that approximately 740 ha of improved pastures had been established by 1992 (Ministry of Agriculture 1995). Currently, the most important extension activity of the pasture programme appears to be the promotion of traditionally-used fodder tree species such as *Ficus roxburghii.*

In the more lowland areas of the western and northern parts of the country, where crop cultivation is common, cereal crop residues are available for use by animals. Limited work has been undertaken with urea-treated rice straw and urea–molasses blocks. Protein supplements are scarce, and current needs for feeding animals are met mainly through imports from India, which are expensive. These include wheat and rice brans, fish meal and soyabean meal.

Animal health

Past efforts have concentrated on epidemiology and disease control measures. The main objectives were to establish efficient mechanisms for monitoring, controlling and preventing major diseases, provide veterinary services and training to farmers, and to develop effective programmes for disease prevention and control.

Over the last two to three decades, the achievements attained include the eradication of rinderpest, the identification of major parasites and parasitic diseases, the identification of major tick-borne diseases (such as babesiosis, anaplasmosis and theileriosis), the economic evaluation and control of foot-and-mouth disease and the control of major zoonotic diseases. Currently, the three main diseases are black quarter, haemorrhagic septicaemia and foot-and-mouth.

Socio-economics and policy

Livestock are an integral part of agriculture in the country and contribute about 10% to the GDP. The policy objectives for the agricultural sector in the ongoing Eighth Five-Year Plan are similar to those of the Seventh plan. These are to (a) sustainably increase the production of food and other crops to meet national demand, (b) improve the income and nutritional level of the population, (c) earn foreign exchange and (d) promote the conservation of the environment and maintain ecological balance. The principal strategy to achieve these goals is the integrated development of crop, livestock and forestry systems within the framework of comprehensive watershed management (Ministry of Agriculture 1995). However, formulation and implementation of practical plans to achieve these goals remain weak because of lack of adequate and accurate data.

The main products from the livestock subsector are used for domestic consumption, and current supplies are inadequate to meet the demands of the nation. It is estimated that about 10% of the livestock products are available for sale and barter (Ministry of Agriculture 1995). The balance is met through imports of milk powder, butter and live animals mainly from India.

Even imported animals are slaughtered on the Indian side of the border and the carcasses are brought into Bhutan as the predominantly Buddhist population dislikes the large-scale slaughter of animals. The urban demand for animal products is increasing rapidly and 70–80% of this is met by imports, primarily from India. There are a number of possible reasons for the failure of the production system to respond to urban demand. First, religious prohibition of slaughter which limits the supply of meat even though there are apparently large numbers of unculled animals in the country. Second, good transport links with India which facilitate cheap imports. However, within the country, poor transport and marketing infrastructure prohibits smallholders from reaching the urban markets. This is particularly the case for milk and milk products. Third, the government follows an open economic and trade policy, and a policy of direct non-intervention in marketing. However, it has a policy of fixing ceiling prices for imported meat products to keep consumer prices low. These ceiling prices serve as a disincentive for local producers to enter the urban market and urban consumers to favour local products. There is clearly a need for assessment of (a) consumption and demand patterns, including consumer preferences and (b) how marketing and policy instruments may be used effectively to encourage small producers to meet that demand, as religious sentiment against slaughter may also discourage the emergence of large-scale commercial production.

Little fresh milk is consumed, so most rural farmers process milk as butter and cheese. To reach the urban market, such products need to have a longer shelf-life and higher quality. There is a need to understand current processing technology, its constraints, and options for improvement. Concurrently, the efficiency of the formal milk marketing and processing channels need to be studied, as all three processing plants are running only at about 20% capacity due to a lack of local milk supplies. Feed is a major problem, particularly for peri-urban and urban producers raising crossbred animals. Feed is also a problem for rural smallholders. Fodder production for animals has been promoted with limited success. One reason is that the fodder has not been integrated into the cropping patterns. Both cropping systems and complementary socio-economic research are needed to identify cropping patterns that can include fodder and the constraints to adoption.

An elaborate land use policy was proposed that considered ownership and transfer rights of pasture and forest land for livestock farmers (nomads and settled) in different AEZs. However, that proposal has never been implemented. With increasing population pressure and other changes in the socio-economic environment, a fresh look at land use and distribution policy is needed.

Institutions

The national research system is relatively new in terms of organisation and research capacity. The research functions of three previous departments (Agriculture, Animal Husbandry and Forestry) have been integrated and placed under the Research, Extension and Irrigation Division (REID) within the Ministry of Agriculture. Research on feeds and fodder comes under REID, but research on animal health and breed improvement continues under the Crop and Livestock Services Division.

Research activities are carried out under three new programmes: breeding and management, health, and feeds/fodder. To support these activities, four research centres have been established, one each for the western, west-central, east-central and eastern regions. An interdisciplinary resource management theme provides the link in the structure for individual programmes at the national and regional levels.

Amongst the commodities, milk followed by meat from pigs and poultry are the most important. Beef is unimportant. The priorities for research, in order of importance, are: feeds and fodder, animal health and breed improvement. Constraint-analysis of the livestock production systems indicated that the low productivity of livestock was due to inadequate feeds and fodder, poor breeding strategies, animal diseases and inadequate management. However, these priorities are influenced by socio-economic factors, which are not represented as priority research areas.

In the past, research on animals has been focused mainly on issues of health. This is reflected in the nature of publications in the Bhutan Journal of Animal Husbandry, given that the eight trained individuals in the country are all veterinarians. Parallel expertise in animal production is essentially non-existent.

The need for a multi-disciplinary systems-oriented research approach is clearly recognised by the Ministry of Agriculture. The proposed integrated natural resource management programme is an example of this new approach. Currently, research capacity is weak and manpower availability severely limited. Training in farming systems research is required urgently.

India

Environment and cropping systems

India is located between latitudes 7°N and 30°N. Since the inception of formal planning in 1951, a number of attempts have been made to categorise the country into different agro-ecological zones (AEZs). The most recent classification divides India into 15 major AEZs (Sastry 1995). These can be grouped further into six broad regions, namely the Himalayas (Western and Eastern Himalayas), the Gangetic plains (Lower Gangetic plains, Middle Gangetic plains, Upper Gangetic plains, Trans-Gangetic plains), the Plateau and Hills (Eastern Plateau and Hills, Central Plateau and Hills, Western Plateau and Hills, Southern Plateau and Hills), the Coast (East Coast Plains and Hills, West Coast Plains and Ghats), the Arid and Semi-Arid North-West (Gujarat Plains and Hills, Western Dry) and the Islands (Andaman and Nicobar Group; Lakshadweep, Dadra and Nagar Haveli Group).

Himalayan region

This region is mountainous with a temperate climate becoming subtropical on the Jammu plains. Annual rainfall varies from 75–175 mm. Forest cover is good (40%); soils are silty loams and the main crops are rice, wheat and maize with oilseeds, millets, tea and fruits as secondary crops. Shifting cultivation is practised in small parts of the eastern Himalayas. The main livestock are sheep, pigs, goats and cattle; transhumance is practised with small ruminants. This region is found in Punjab, Himachal Pradesh, Jammu and Kashmir, Assam, West Bengal, Sikkim and other small eastern states.

Gangetic plains region

The vast Gangetic plains run along river systems (Beas-Sutlej, Ganges-Yamuna and Brahmaputra) from the extreme western sub-mountainous parts to the Bay of Bengal in the east. Forest cover is <9% and many of the soils are alluvial. Erosion and salinity problems occur in the region. The climate is subtropical; cold in winter (with frost) and hot in summer. Annual rainfall varies from <500 to >1000 mm. The region is the major zone for rice and wheat production. Other crops of importance are maize, pulses, oilseeds, jute, pearl millet, cotton and sugar-cane. Significant areas are under irrigation. In the Lower Gangetic Plain, mustard and potato are increasing in importance. High buffalo densities occur in the region along with significant numbers of goats and cattle; dairy production is a major activity in the region. The Gangetic Plains are found in the states of West Bengal, Bihar, Uttar Pradesh, Punjab, Haryana and Rajasthan.

Plateau and hills region

This region covers the largest land area of India extending from the southern fringes of the Indo-Gangetic Plains deep into peninsular India (excluding the coastal regions). The climate is tropical, semi-arid and subhumid (annual rainfall <500 to >1000 mm) and forest cover ranges from 11% to 30%. Dryland crops such as the millets, sorghum and pulses predominate, although rice, cotton, oilseeds, sugar-cane, bananas and horticultural crops are also grown. The largest proportion of sheep and goats are found in this region along with cattle and buffalo in the southern and western areas. Dairy and poultry production are of importance. The region is found in the states of Bihar, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, Andhra Pradesh, Rajasthan, Karnataka and Tamil Nadu.

Coastal region

This region runs along the length of peninsular India on its eastern and western fringes. The two coastal areas comprising the region are quite different from each other. The annual rainfall is much higher in the western area (2000–4000 mm) than in the eastern area (780–1300 mm). In the west, the forest cover is 57% compared to about 10% in the east. Some of the most fertile soils of India occur in the east and include alluviums, loams, clays and black soils. However, alkaline and saline soils also occur. In the west, soils include laterites, loams and clays. In the east, the irrigated area ranges from 38% to 86% and in the west from 7% to 33%. Shifting cultivation is practised in small areas in the east. The most important crops in the east are rice and groundnuts whilst plantation crops and spices are of importance in the west. Buffalo and sheep are the preferred species in the east and cattle and goats in the west. Both regions have benefited from cattle crossbreeding for dairy production. The region is found in the states of Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra and Goa.

Arid and semi-arid north western region

This region is mostly arid and semi-arid and covers the eastern fringes of the Thar Desert. In the Western Dry part, annual rainfall is <500 mm with wide annual fluctuations. Soils are either sands or loams. Agriculture is predominantly rainfed and the region is drought-prone. Less than 23% of land is irrigated. Forest cover is <5% and waste and fallow areas occupy 42% of the land. The region is important for pearl millet, wheat, pulses and oilseeds. Cattle, sheep, goats, buffalo and camels are important in the Gujarat Plains and Hills; transhumance is practised with small ruminants. This region is found in the states of Gujarat and Rajasthan.

Islands region

This region is equatorial with annual rainfall of 3000 mm spread over 8 or 9 months. It is largely a tropical rainforest zone with a high density of coconut. Livestock play a nominal role in the farming systems although scope exists for their inclusion in plantation crops.

Soils and cropping

In India, alluvial soils (loams, sandy loams and loamy sands) cover about 143 million hectares and have relatively low nutrient levels and water-holding capacities. The pH of these soils is neutral to alkaline. Major crops grown on alluvial soils include rice, wheat, maize, pigeonpea, mustard and chick-pea. Red soils cover 66 million hectares in India and are characterised by clay contents of 10–20%, poor fertility and relatively low water-holding capacities. Red soils are slightly acidic in reaction and are found in areas of high rainfall and temperature. Major crops associated with red soils are groundnut, pearl millet, pigeonpea, rice and black gram. Black soils cover an area of about 61 million hectares and are more productive than other soils. Clay contents vary from 30–70%, and the soils have high nutrient and water-holding capacities. Major crops associated with black soils are cotton, sorghum, pearl millet, pigeonpea, soyabean, chick-pea and linseed. Desert soils (sands, loamy sands and sandy loams) cover about 15 million hectares of land, and are poor in nutrients and water-holding capacity. Subsoil salinity is common as is wind erosion. Major crops grown in these soils include pearl millet, green gram, pigeonpea, chick-pea, sorghum and cowpea. There are approximately 44 million hectares of mountain, sub-mountain and skeletal soils that are silty loams. These soils are vulnerable to landslides and erosion, and are of low fertility. Major crops associated with these soils are maize, soyabean, rice, wheat, mustard and chick-pea.

To summarise, India has varied land use patterns and diverse cropping and livestock systems. The majority of land falls into the arid/semi-arid climatic classification. As an approximation, most of the western half of the sub-continent is arid (<500 mm rainfall) and semi-arid (500–1000 mm rainfall), whilst much of the eastern half is subhumid (1000–1500 mm rainfall) and humid (>1500 mm). The coastal strips of western peninsular India and small parts of the Western Himalayas are also humid. Accordingly, the number of crop growing days varies from 60 days in the north-west to 300 days in the east.

Animal genetic resources

Livestock in India form a sizeable proportion of the world population of individual species: approximately 53% of the buffalo, 20% of the goats, 15% of the cattle, 4% of the chickens, 4% of the sheep and 1% of the pigs. Of these, goats and poultry have shown steady growth over the last three decades.

Livestock are distributed throughout the country with marked concentrations in certain AEZs. Cattle are concentrated in the Lower and Middle Gangetic Plains and the West Coast Plains and Ghats, where they are used intensively for both milk and draft purposes. Lower concentrations are found in the Plateau and Hill regions. Similarly, buffalo are also concentrated in the Gangetic Plains, in the Central Plateau and Hills and in the Coastal region, where they are valued for milk production. Generally, goats and sheep are reared together, usually in the drier semi-arid parts of the country in the Western Dry region and the Southern Plateau and Hills region in Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat and Andhra Pradesh. Sheep, especially the wool breeds, are found in the more temperate areas of the Himalayan region. Both species are associated with extensive nomadic and transhumant migrations lasting for between 4 and 6 months annually.

An analysis of buffalo and cattle production trends between 1966 and 1987 indicated that in the eastern region comprising Assam, Bihar and Madhya Pradesh numbers of draft animals, both cattle and buffalo, have increased significantly, but the number of dairy animals have only increased marginally. In the northern, southern and western regions the number of draft animals, particularly cattle, have decreased but dairy animals, particularly buffalo, have increased significantly.

India is rich in indigenous animal genetic resources. These include 26 cattle breeds, 8 buffalo breeds, 40 sheep breeds and 20 goat breeds. There are also many indigenous breeds of pigs and poultry. Amongst these are several well-known cattle breeds such as the Gir and Hallikar for milk; Hariana, Ongole and Kankrej for draft and milk; the Murrah and Surti buffalo breeds; the Jamnapari and Beetal goat breeds for milk and the Barbari for meat and milk; and in sheep the Chokla breed for carpet wool, the Marwari for meat and carpet wool and Nellore for meat.

Improvement programmes, mainly involving crossbreeding, have tended to focus on cattle for milk production. Less attention has been given to selection and improvement within breeds. Limited breeding and selection programmes are underway with the buffalo. Several European goat and sheep breeds have been introduced into India for crossbreeding with indigenous breeds with variable success, and this is more conspicuous in sheep than in goats. Many cattle, buffalo and small ruminant breeds have been exported from India and introduced into other countries in Asia for use in crossbreeding programmes.

Dairy development has received overwhelming attention and has resulted in spectacular success through 'Operation Flood', in which about 79 million buffalo produce approximately 55% of the total volume of milk compared to about 40% from 199 million cattle (Gupta 1996).

Animal production systems

Buffalo and cattle predominate in arable areas, where they utilise crop residues and provide draft power and manure. This is the case in the Gangetic plains in Haryana, Uttar Pradesh and the Punjab, where irrigated wheat and rice production is common. Similar situations exist in the lower rainfall areas in Andhra Pradesh and Tamil Nadu. In the drier areas of Gujarat, Rajasthan and Maharashtra, cattle (and to a lesser extent buffalo) are found in extensive systems where they are used for draft purposes and haulage.

Dairy production, involving buffalo and crossbred cattle, is the major thrust in animal production. The milk is produced mainly in smallholder systems where the animals are tethered or stall-fed. With the expansion of peri-urban dairy production, there is an increasing interest in intensive systems of production and the development of improved stall feeding, in which purchased feeds such as chopped straws and green fodder are brought in from the rural areas. Most of these feeds are purchased, often at high cost, since milk production is a lucrative business. However, there are also emerging problems related to milk handling and hygiene and environmental pollution. The choice of either buffalo or cattle for milk production is dependent on location as well as the availability of animals. Often, both species are used together by smallholders to combine the different butterfat contents. In situations where there are already significant numbers of buffalo and abundant feed resources (Haryana and Uttar Pradesh) buffalo production is increasing.

'Operation Flood', managed by the National Dairy Development Board (NDDB), has used an integrated approach to production, procurement, processing and marketing of milk along co-operative lines. This is reflected in a 4.7% annual growth rate in milk production, 70 million tonnes of milk produced in 1997, benefits to >10 million member households, increased urban consumption and the use of about 90% indigenous dairy equipment. The beneficiaries include 60% of the landless and small farmers for whom increased milk production and incomes has enabled children to go to school (Patel 1998).

Goats and sheep are reared in extensive systems involving nomadism and transhumance in the arid/semi-arid areas. This is related to the constant search for feed in areas of low production where animals move long distances during many months. Of particular significance is that the system involves the poorest people, including the landless. In these same areas, there has been a shift away from cattle and buffalo towards goats because of their dual-purpose value and the high demand for their meat and milk. Both cattle and buffalo are also integrated, to a lesser extent, with crop cultivation throughout the plateaux in Madhya Pradesh, Andhra Pradesh and Tamil Nadu and the response of farmers to on-farm interventions is very promising (Raghavan et al 1991). In southern India, there is increasing interest in intensive stall-feeding systems for goat production. The integration of small ruminants with perennial tree crops such as coconut and fruit trees remains to be developed.

Recently, a major review of the livestock subsector was undertaken in India (World Bank 1996). This assessed the technical and economic situation, constraints to development and opportunities. A plan of action was drawn up. Of special relevance to our study was the recommendation that research efforts should be re-oriented to focus on smallholder farming systems, management, feed and fodder production, breeding schemes, and the testing of available technologies.

Feed resources

The main feed resources in India include native grasslands, cultivated fodders and trees, crop residues, agro-industrial by-products (AIBP), and non-conventional feed resources (NCFR).

There has been a gradual reduction in grazing resources due to the increasing use of these lands for crop cultivation. Pasture supplies about one-third of the total feed resources used by ruminants. As a result of a breakdown in the traditional management of common property resources, these areas are currently in a state of degradation throughout the country with low vegetation cover and a high vulnerability to erosion. The grazing intensity on these rangelands has been estimated to be 2–6 adult cows/ha per year with very wide variations depending upon the density of ruminants in an area (Singh et al 1995a).

Where intensive cropping is common, native pasture and cultivated fodder contribute little to ruminant diets. In such areas, crop residues are the major feeds and are increasing in importance; the principal residues are the straws of cereals and pulses. However, estimates of the annual availability of different crop residues (Devendra 1997; Mahel 1997; Singh et al 1997) vary greatly between authors (wheat 55–74 million tonnes; rice 74–152 million tonnes; sorghum 23–47 million tonnes; groundnut 14–31 million tonnes), reported in Renard (1997). Also, data on the extent of use of these feeds are not available. In the Gangetic Plains, characterised by the highest intensification of grain production and with a significant ruminant population, the availability of crop residues is higher than calculated requirements. However, in Punjab State, up to 80% and 50% of rice and wheat straw, respectively, are burned in the field and an estimated 17.3% and 51.5% of the total rice and wheat straw, respectively, are used as feed for ruminants. Type and quality of crop residues vary according to the AEZ and the cropping patterns adopted.

In the arid/semi-arid areas, crop residues supply most of the animal maintenance requirements. In these areas, sorghum and millet are very important sources of roughage for ruminants. Sorghum is the preferred source of fodder for dairy animals (Kelley and Rao 1995). However, sorghum and millet stover production has declined significantly mainly due to a decrease in the cropped area and the use of new varieties with a higher harvest index. These decreases have resulted in a shortfall in roughage availability, and have led to a significant increase in the price of these crop residues, with resultant hardships for landless milk producers. A tenfold increase in fodder price coincided with only a fourfold increase in grain price with the grain:stover ratio price declining from 6:1 to 3:1. The value attached by rural and landless farmers to sorghum and millet stover has slowed down the decrease in the area of these crops for grain.

In the irrigated areas, crop residues such as wheat and rice straw, and sorghum and millet stover are fed in mixtures with green fodder by small farmers. The increasing land area under oilseed production in Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu is reducing fodder availability for livestock. The use of short-strawed and dwarf cultivars of traditional crops such as pearl millet, sorghum, rice and wheat also reduces fodder availability and farmers balance the planting of these cultivars with traditional landraces according to their need for animal fodder. Considerable component research has been conducted on the biological and chemical treatment of cereal straws (Singh and Schiere 1995). However, these studies have been conducted largely on station and there has been little adoption at farm level.

Cultivated fodders account for only 3.3% of the total cropped area in the country. Over the years, fodder cultivation has increased in irrigated areas and has declined in rainfed areas. In the northern states of Uttar Pradesh, Madhya Pradesh, Gujarat, Rajasthan and Haryana, cultivation of fodders such as berseem and oats in the cool season and fodder sorghum and maize in the summer are common in irrigated areas, and account for more than 75% of the total cultivated fodders in the country. There has been a discernible shift to the growing of fodder crops in areas covered by milk procurement schemes either by government, co-operatives or privately-owned agencies. Sugar-cane tops are also available in irrigated areas.

AIBP include rice and wheat bran; groundnut, rapeseed, soyabean, sunflower and cottonseed cakes; and cereal and brewers grains in that order of importance. The estimates of availability are based on crop yield data and established extraction rates. However, detailed estimates of the amounts actually used in ruminant diets is lacking. In addition, brans and cakes are used more in peri-urban and urban areas than in rural areas. In addition to sugar-cane tops, the major by-products of the sugar industry are molasses and bagasse. Most of the bagasse is used as fuel in the sugar factories and <10% of the 3.0 million tonnes of molasses produced are available for animal feeding. The improved utilisation of these feeds was addressed through the All-India Coordinated Agro-Industrial By-Products Project involving many components and participants from the state universities and non-governmental organisations (NGOs). Although a number of on-station research outputs are available, there is little transfer of technology on-farm. A number of multi-purpose trees are used by smallholder farmers including *Leucaena leucocephala, Gliricidia sepium* and *Prosopis* species. However, quantitative data on availability of forage from fodder trees are scarce. The importance of *Acacia nilotica, Prosopis cineraria* and *Azadirachta indica* is evident for example, in Rajasthan for goat production. These fodder sources represent 80% of the diet of goats during the 5–8 long dry months of the year and about 40% during the rest of the year. Most studies related to fodder tree utilisation are conducted on research stations without considering the potential interactions resulting from the mixed grazing of livestock competing for the same source of feed during periods of stress.

An estimated 12 million tonnes of NCFR are produced annually and represent a large potential source of supplements for ruminants. They include rubber seed cake, spent anatto (*Bixa orellena*) seeds, cassava starch waste, sal (*Shorea robusta*) seed meal, panewar (*Cassia tora*) seed, mango seed kernels, babul (*Acacia nilotica*) seeds, vilayati babul (*Prosopis juliflora*) pods, warai (*Panicum milliceum*) bran, tamarind (*Tamarindus indica*) seed, niger (*Guizotia abyssinica*) seed cake, ambadi (*Hibiscus cannabirus*) cake, kokam (*Garcinia indica*) cake, damaged apple waste, karanj (*Pongamia glabra*) cake, coconut pith, mahua (*Madhuca indica*) seed cake, kosum (*Schleichera oleosa*) cake, cocoa pods and castor bean meal. The utilisation of these feeds can be increased significantly with improved processing technologies reducing the negative effects of some of the anti-nutritional factors present (hydrocyanic acid, tannins, mowrin and karanjine).

Animal health

A wide range of viral, bacterial and parasitic diseases affect Indian livestock and poultry. There are also reproductive, metabolic and mineral disorders in ruminants, and toxicosis and mycotoxicosis in animals raised in peri-urban and urban areas as a result of environmental pollutants and feed adulteration. Important diseases in large ruminants include foot-and-mouth, anthrax, haemorrhagic septicaemia, black quarter and theileriosis; pox in sheep and goats; swine fever in pigs; and fowl pox, cholera and Ranikhet disease in poultry.

Animal production and health is the responsibility of the state governments. Health care is provided through clinics/veterinary hospitals/dispensaries which have increased in number from 2044 in 1991-92 to 21,718 during 1993-94. Similarly, the number of first aid centres, including mobile dispensaries, also increased from 19,360 in 1991-92 to about 20,044 in 1993-94. This infrastructure is supported fully by 250 diagnostic laboratories in the country. By the turn of the century there will be one veterinary unit to meet the needs of 5000 cattle units or 10 villages. In addition, diagnostic and vaccine production activities are being undertaken by the institutes of ICAR, NDDB and the state agricultural universities. Although at present diagnosis and vaccine production by various agencies are based on old methodologies, biotechnology is becoming increasingly available for developing diagnostic tools and vaccines (Singh 1996).

There are 26 vaccine production units (19 in the public sector and 7 in the private sector) in the country. These institutions are engaged in the production of various types of viral and bacterial vaccines. In addition, 13 different antigens are also being produced. ELISA-based diagnostic tests for brucellosis, rinderpest and peste des petits ruminants (PPR) have also been developed. The production of vaccines for the major diseases increased from 190 million doses in the mid-1970s to about 1250 million doses currently.

The existing system for reporting diseases is not organised. This reporting system is passive and with poor diagnostics, does not allow for reconfirmation of the disease. A lack of reliable data is usually interpreted as the disease. At present, the reporting system operates through state animal husbandry departments. ICAR has launched an All-India Coordinated Research Project (AICRP) on Animal Disease Monitoring and Surveillance (ADMAS), which has made a significant contribution to the development of simulated animal disease-forecasting models. The incidence of many of the diseases has declined and some have been controlled. Foot-and-mouth disease is one of the major animal diseases in the country and it is a serious constraint to the international trade in livestock and animal products. The disease is endemic and occurs in all parts of the country throughout the year. The main serotypes found are 'O', 'A', 'Asia 1' and 'C'. Of these, type 'O' is responsible for about 70% of all the outbreaks. Type 'C' is the least prevalent. Although the mortality is low, the morbidity rate is high and this causes heavy economic losses in milk production and a reduction in the work output of animals. The direct loss due to this disease is estimated to be more than US$ 430 million per year. In addition, milk, meat and hides are not accepted by other countries, further reducing the export potential of the livestock industry.

The work carried out on foot-and-mouth disease during the last three decades has helped identify the prevalence of the disease, the distribution of the virus types, and the development of quality diagnostics for precise typing and antigenic analysis. The disease is being controlled by regular vaccination of animals, but this is limited to a small population of selected animals/herds on well-managed farms, which constitutes less than 2% of the susceptible population. To boost the export of livestock and livestock products, the concept of disease-free zones (DFZ) is being promoted. At present, four districts in the south of the country have been identified as DFZs.

For the control of rinderpest, a European Union-assisted programme was launched during the Eighth Five-Year Plan. The disease has now been successfully controlled and no outbreaks have been reported in the last two years. The disease was controlled by dividing the country into four zones for closer supervision and monitoring. The veterinary health infrastructure developed under the programme has been proposed for use in the control of other diseases in the future.

Various vaccines and diagnostics against different diseases of livestock and poultry have been developed in the recent past. In addition, indigenous drugs and medicines against various infectious and non-infectious conditions have been developed and are being used routinely by farmers. However, the methodologies have not been adequately adopted under field conditions due to a lack of basic infrastructure, poor technology delivery and lack of effective linkages at various levels. Despite the development of vaccines/drugs against important diseases, instances of vaccine failure, development of drug resistance in pathogens and the emergence of strain variants of pathogens have been reported.

The following future strategies and priorities for animal health are relevant:

- development of a new generation of vaccines and diagnostics, diagnostic technologies/methodologies, and immunobiologicals against important livestock and poultry diseases
- development of centres of excellence for species-specific disease diagnosis and the establishment of better co-ordination and linkages at national and international level
- strengthening of monitoring and surveillance systems to develop an animal disease database, and the evolution of strategies for the control of animal diseases at the national level
- increased research on various exotic diseases to tackle their control by specialised laboratories
- modernisation of a biological production unit to create a national quality control laboratory
- further research on environmental pollutants and toxicants, mycotoxins and mycotoxicosis
- establishment of a network for research on parasitic diseases.

Socio-economics and policy

In the Ninth Five-year Plan, the policy goals of the livestock subsector were defined in terms of alleviation of poverty, improvement of human nutrition (particularly of the poor), creation of productive employment, enhancement of wealth of the rural poor and the empowerment of rural women.

Forty per cent of the rural population live below the poverty line. Some 58% of the rural households are landless or marginal farmers owning up to 0.5 ha of land, 16% own 0.5 to 2 ha of land, 18% own 2–5 ha and 8% own >5 ha. Ownership of livestock is more equitable than land ownership as landless, marginal and small farmers have a larger share of the livestock population relative to their proportion in human population terms. Consequently, livestock play an important role in alleviating rural poverty and reducing income inequality. About 25% of the rural population are involved directly in livestock production and management. Additional employment is provided by processing and marketing activities. Women play an important role in livestock production and decision making.

Current consumption of meat and milk is about 4.3 and 68 kg/per capita/year, respectively. Rural consumption levels are lower. Significant increases in production will be required to improve these consumption levels if human nutrition and health are to be improved. Animal products contain essential amino acids, and even small amounts of these compounds in the daily diet help to improve human health significantly.

Although the policy goals for the livestock subsector are relatively clear, the strategies and policy instruments to achieve these goals are less clear. Historically, government policies tried to influence the livestock subsector through three types of interventions. First, government departments and corporations were involved in livestock production, processing and marketing. A huge infrastructure was developed and staff engaged to provide veterinary and animal production services. City milk schemes were created in all major towns and cities to supply cheap milk to urban consumers. Extensive research establishments were created to support livestock development. Second, an extensive regulatory framework has been created to influence the actions of private decision makers in the livestock subsector. However, the policy framework has been more restrictive than liberating. Government controls the prices at which co-operatives and public sector enterprises buy milk from farmers and sell products to consumers. A licensing policy was enforced until recently to prevent private sector investment in dairy processing. Thirdly, direct and indirect taxes on livestock activities are low but subsidies have been used extensively to supply services (animal health care and artificial insemination), and provide credit under integrated rural development programmes for livestock. However, the extent of subsidies to the livestock subsector has been small compared to subsidies to the crop subsector.

These policies and policy instruments have often failed to achieve the desired goals due to problems of targetting and a lack of strategic leverage (Shah et al 1996) and sometimes produced unwanted results. For example, government corporations and city milk schemes have in many cases failed to deliver quality milk and milk products at affordable prices in a sustained manner. Disease control and eradication, abattoir management and livestock product quality control are major areas of activity where public sector involvement may be effective in developing economies, as markets do not often encourage private sector initiatives in these areas. Subsidised government efforts in these fields have failed to deliver quality services to the vast majority of the rural poor. At the same time, they have prevented the creation of opportunities for the private sector. Rarely has subsidised livestock credit reached the intended poor farmers.

Dairy co-operatives have played a significant role in disseminating crossbred cows and related technology packages, and have contributed to the success of 'Operation Flood.' However, licensing to prevent private enterprise involvement in dairy processing has created a government monopoly, and this has led to the inefficiency of many co-operative enterprises. Without government support they lack viability and fail to become truly farmer-owned enterprises (Doornbos and Gertsch 1994). The success of the private sector initiative in the poultry industry has contributed to meeting rising demand for meat, but has by-passed the rural poor. The experience of commercial poultry development, therefore, may not be fully applicable to the ruminant sector because of the dominance of smallholders in this sector. However, many lessons learnt on the functioning of market forces in shaping an industry can be applied fruitfully to the ruminant sector.

Despite heavy direct government involvement at considerable cost to the national exchequer, government policy has not been able to shape or decisively influence the direction of the livestock subsector. One of the reasons for this is the poor linkages between policy, research and extension and, more importantly, a research system that has failed to generate appropriate technologies for the smallholders.

Institutions

There are principally two sets of research institutions: commodity or discipline-oriented research institutions co-ordinated by ICAR and the state agricultural universities (SAU) with a mandate for teaching, research and extension. The SAU also get funds for research from ICAR. SAU generally pursue a research agenda within their mandate areas, which in some cases may be only part of a state. Although some of the research conducted by SAU may be of a strategic nature, having relevance within and outside India, their primary research agenda for both crops and livestock is of an applied and adaptive nature.

Commodity-oriented ICAR institutions are supported by relevant disciplines but there are two deficiencies in the approach. First, the single mandate commodity (e.g. milk) is studied as an isolated enterprise rather than as part of a mixed farming system in which crops and different livestock species interact. Second, the disciplines also work in isolation from one another rather than addressing the mandated commodity in a multi-disciplinary manner.

The oldest discipline-oriented ICAR institute is the Indian Veterinary Research Institute (IVRI). Research involves many animal species and many diseases without systematic prioritisation. The IVRI has succeeded in developing a number of vaccines in the last 100 years and has kept health and production-related disciplines within its research programme. However, in practice the work is undertaken in isolation and not in a holistic manner. The choice of diseases for vaccine production and the volume of production are not based on systematic epidemiological studies or the ranking of the severity of the chosen diseases.

Social sciences, particularly agricultural economics, is strong in the SAU and in the National Dairy Research Institute (NDRI), but very weak in other ICAR institutions. In general, involvement of social sciences in research priority setting and research/technology design is minimal. However, most ICAR institutes have field-based research, some for a longer duration than others. These are defined variously as operational farming system projects, on-farm research projects, and technology assessment/transfer projects. These are generally multi-disciplinary projects in which a sequence of steps (Participatory Rapid Rural Appraisal and survey for characterisation; constraint identification; component-technology intervention; and assessment of their performance) is followed. Although an enormous amount of data are collected in these projects, only a small fraction are analysed. These are formulated as integrated projects, yet the assessment is made for individual interventions and enterprises separately, so the effects of integration and interaction are not captured. The analysis does not consider the system as a whole, the changes due to intervention, and an assessment of the flow of costs and benefits between crop and livestock enterprises.

Across SAU and ICAR institutions, socio-economics research in the farming system context is focused on the relative economics or profitability of different breeds of cattle and buffalo, the economics of fodder production for dairying, the economics of processing technologies, the role of livestock in income generation, the effects of access to dairy co-operatives and the efficiency of dairy marketing through co-operatives. The results of these micro-level studies are not always synthesised to draw lessons for technology development and diffusion.

In support of the dairy industry, the NDDB is also involved in applied research to improve breeding, feeding and healthcare in dairy animals. Progeny-testing programmes for selection of bulls for semen production, development of urea–molasses blocks fortified with anthelmintics, and the development of rapid on-farm tests for diagnosis of various diseases (calf scour, foot-and-mouth, bluetongue, tuberculosis) are some examples of the NDDB activities.

Nepal

Environment and cropping systems

Nepal is a land-locked country located between latitudes 26°N and 30°N. It is situated along the southern slopes of the central Himalayan region, and covers an area of 147,000 km^2 (Shrestha and

Pradhan 1995). The country is divided broadly into three agro-ecological zones (AEZs), the Tarai, the Mid-Hills and the Mountains. The highest proportion of cultivated land (40%) is found in the Tarai, where 60% of the cereal grains are produced; a further 44% of the Tarai is forest. In the Mid-Hills and Mountains, much of the land area is not cultivated and is under grazing (9% and 22%, respectively) and forest (52% and 29%, respectively). There are about 2.6 million hectares of grasslands and other grazing lands in the Mid-Hills and Mountain zones.

The Tarai, which is in the south, runs from the east of the country to the west and covers 3.4 million hectares. The region is part of the Gangetic Plain. Altitude ranges from 76–280 m above sea level and the climate is subtropical and humid, with an average annual rainfall of 1600 mm. Temperature ranges from 25–32°C in summer and from 8–24°C in winter. The soils are alluvial. The Mid-Hills, situated to the north of the Tarai, are generally of rugged mountain topography dissected by north to south drainage systems. Altitude ranges from 800–2400 m and the land area is 6.1 million hectares. Mean annual rainfall is about 1800 mm, and temperatures in summer range from 20–30°C and 8–18°C in winter. Some 93% of the total human population of Nepal is found in the Tarai and Mid-Hills regions. The Mountain zone, covering 35% of the land area, lies above the Mid-Hills, with elevations rising from 2400 to 8848 m. Some areas are cold arid/semi-arid deserts, and annual rainfall ranges from 200 to 800 mm. Above 4000 m altitude, there are extensive Alpine grazing areas.

Crop production is very dependent on livestock for draft power and manure. Crop production is practised largely on terraced slopes, and farming systems are mixed, diverse and subsistence oriented. The wide range of crops cultivated are in response both to varied agroclimatic conditions and to the risk-reducing objectives of farmers. Rice, wheat, maize and finger millet are the main crops grown. Typical examples of cropping systems have been reported by Reynolds et al (1995):

- Tarai: maize–wheat–fallow and rice–wheat–fallow (rainfed); rice–rice–wheat and maize–rice–wheat (irrigated).
- Mid-Hills: maize/finger millet–wheat, maize/soyabeans–wheat and maize–finger millet–fallow (rainfed); rice–rice–wheat and maize–rice–wheat (irrigated).
- Mountains: maize–wheat–finger millet and maize–potato–wheat–finger millet in a two-year rotation (rainfed); rice–barley and potato–barley–fallow in a two-year rotation (irrigated).

Cash crops are scarce, but some tea and cardamom are planted; vegetables, fodder trees and fruit trees are grown widely. At lower altitudes, mango and jackfruit are established and, at higher altitudes, citrus, banana, plum and peach are grown. On-farm soil fertility is maintained at the expense of off-farm fertility, due to nutrient transfer from forest and open grazing areas, which are under great pressure in the more densely populated areas. On terrace edges, there has been an increase in the cultivation of grasses which helps to reduce erosion. When animals are tethered on the terraces, urine and dung deposition provides a mixture of readily available nutrients and organic residues.

Animals grazing on grasslands, usually under communal management, have caused problems of overgrazing and land degradation. Stocking intensities, well in excess of optimum carrying capacities, have led to over-extraction of vegetative biomass from forest and open grazing areas. This has contributed to very high levels of soil erosion (8 t/ha per year from land under forest; 35 t/ha per year from grassland) and to an increase in noxious weeds.

Grasslands are classified into Mountain pastures (>1800 m), Hill pastures (500–1800 m) and Tarai pastures (<500 m). In the Mid-Hills and Mountain zones, animals remain grazing around the villages during the day, returning at night or they are stall-fed. In the high-altitude pastures, transhumance is practised where animals are away from the village for much of the year. However, this system is declining and migratory flocks from Nepal that traditionally grazed the native pastures on the Tibetan Plateau in China have been denied access since 1988.

Animal genetic resources

In terms of distribution of livestock by households, 76.6% keep cattle, 48.5% keep buffalo, 51.3% keep goats and 51.9% keep poultry. The ruminant population is concentrated in the hills and mountains. About two-thirds of livestock keepers are smallholders, who own <1.0 ha of land. Women make a significant contribution to animal agriculture. There is considerable diversity in the animal genetic resources notably cattle, goats and sheep. With both buffalo and cattle, several Indian breeds have been introduced, but the crossbreeding of the Holstein-Friesian for milk production is the most common. Several exotic goat breeds have also been introduced for crossbreeding with the native Khari. Exotic sheep breeds such as the Merino have been introduced for improved wool production. Amongst indigenous breeds, Baruwal sheep and Sindhal goats are used in the high mountains for transportation of goods. Yak are found at about 4200 m altitude and are an endangered species.

Animal production systems

Buffalo and cattle are reared in mixed farming systems where cereals are cultivated (mainly rice and wheat). Both species make a significant contribution to the supply of draft power and manure. Cattle are also valued for milk production. The demand for milk, and the rate of growth in milk production is expected to increase by 8.5% annually. This is associated with expanding peri-urban dairy systems, mainly around Kathmandu, and is based on the use of cereal straws, fodders and concentrates. This sector has a high priority for research.

Small ruminant production is found mainly in extensive nomadic and transhumant systems in the hills and mountains. The animals grazing in these environments walk distances of 10–15 km daily, often in forest areas to search for feed during spring and summer. With the onset of winter, the animals move to lower altitudes and to the Tarai. Wool production from sheep is on the decrease due to limited markets. For small ruminants, good opportunities exist for stratification of production in which multiplication of numbers in some areas can be combined with semi-intensive and intensive systems of production in others where feeds are abundant. Recently the World Bank approved technical assistance and support for the development of small ruminant production in Bandipur, and pastures and fodders in Khumaltar (World Bank 1997).

Feed resources

Feed resource issues have to be addressed in the context of the three main AEZs. In the Tarai bunds, terraces, fallow land, cultivated land after harvest and forest areas constitute the main sources of grazing areas for ruminants. Crop residues and agro-industrial by-products (AIBP) are also fed to ruminants. In the summer, green forage is harvested from croplands and the bunds. In the Mid-Hills, grazed fallow lands, crop residues (rice, wheat, maize, millet and barley) and forest fodder represent the major feed resources for ruminants. In the Mountains, Alpine pastures and forest fodder are the main sources of feed for livestock. Some hay is made in summer from Alpine pastures. Cattle and buffalo graze Alpine pastures in the summer; in winter the animals return to the Mid-Hills where they feed on crop residues as well as graze fallow lands.

The main contribution to feed energy and protein for ruminants comes from cereal straws (53%). Other sources include forest fodders (16%), native pasture grazing (11%), shrubs (9%), rice bunds (5%), fallow grazing (4%) and farm-grown fodders (2%). Whilst crop residues and fallow grazing represent 67% of the feed in the Tarai, this decreases to 27% in the Mid-Hills and to 6% in the Mountains. Some 76% of feed comes from grazing native pastures in the Mountains, but this decreases to 18% in the Mid-Hills and to only 6% in the Tarai. The contribution of fodder from forests and bunds is greatest in the Mid-Hills (50%). Similarly, shrubs contribute more as feeds significantly in the Mid-Hills (62%) than in the Mountains (32%) and Tarai (6%).

Most of the agricultural lands are in the Mid-Hills and Tarai, and are the main source of crop residues for livestock feeding. Rice straw accounts for more than 50% of the contribution to the total nutrient supply from crop residues, especially during the winter months and in the dry summer periods. Depending on availability and social practices maize, millet, wheat, barley, sorghum, mustard and soyabean residues are used as feed during the dry season. Observations from the results of feeding trials with urea-treated straw have demonstrated its value. However, farmers have not adopted this technology, for various reasons such as high cost. Crop residues are fed according to their seasonal availability and only in urban areas are they fed in association with protein supplements or grains. Oilseed cakes, rice by-products, sugar-cane tops and banana leaves/stems are fed to ruminants. Brewers grains and water hyacinth could also become significant sources of feed in the future.

Leaves of multi-purpose trees are an important supplement for large and small ruminants, especially during the winter and summer dry periods. However, the variation in nutritive value and anti-nutritional factors in these fodder trees is considerable. The main fodder trees used include *Artocarpus lacucha, Litsea monopetala, Quercus semicarpifolia, Ficus semicordata, F. roxburghii, F. lacor, Garuga pinnata, Bauhinia purpurea* and *B. variegata*.

Animal health

Animal diseases are a continuing threat to animal production. Most of the animal diseases of economic importance are endemic in the country and cause losses in animal production of up to 40%. These include foot-and-mouth disease; haemorrhagic septicaemia, black quarter, theileriosis, babesiosis, fascioliasis and rinderpest in ruminants and Ranikhet disease, Gumboro and coccidiosis in poultry. A number of exotic diseases such as peste des petits ruminants (PPR) in small ruminants, infectious bursal disease in poultry, foot rot in sheep and theileriosis in large ruminants have been introduced into the country through the importation of live animals, live vaccines and animal products. Khari disease is a chronic condition of unknown etiology in lactating buffalo in the western hills of Nepal.

Internal and external parasites are also a problem in livestock. Due to indiscriminate use of various anthelmintics, drug resistance has developed. There is a need for proper drenching schedules and anthelmintics suitable for species in the different AEZs. Posterior paralytic syndrome in goats in the mid-west region is also reported to cause economic losses. Reproductive problems are evident in dairy cattle. With an increase in exotic cattle and crossbreds in Nepal, haemoprotozoal diseases have become a problem.

Priorities for research in animal health include the need for (a) epidemiological studies of diseases in different species in the various AEZs, (b) immunological investigations of diseases for development of suitable vaccines, (c) the testing of imported vaccines to determine efficacy under local conditions, and (d) the exploitation of indigenous plant species with potential for use in veterinary medicine.

Socio-economics and policy

The primary focus of government policy has been in the crop subsector because of its larger contribution to the economy and the need to increase food grain production for the rapidly increasing population. Direct policy and institutional support to the livestock subsector is in two different forms, viz. provision of veterinary services with free or subsidised drugs and the establishment of livestock farms to supply improved breeds to farmers. The veterinary service structure is highly inadequate to serve the needs of most of the farmers, particularly in the hill areas where most of the livestock are raised. Although uncontrolled animal movements across the large open border with India pose a serious threat to indigenous animals in terms of spread of diseases, the capacity for disease surveillance is poor.

The government livestock farms established to serve as a vehicle for improving livestock productivity have made little impact except in the case of dairying. The development of dairy production has emphasised crossbreeding and the development of marketing and processing infrastructure, particularly around the capital Kathmandu. During peak production, there is surplus milk as demand in the capital is limited by low per capita income. However, in the off-peak season, there is a shortage of supply from local sources, so powdered milk is imported from India for reconstitution. This seasonal imbalance, coupled with a liberal import policy, is a major constraint to the development of the domestic subsector. Currently, options being considered are an expansion of processing capacity, an extension of the supply hinterland and the building of internal capacity to produce milk for use in the off-peak season. The possibility of small-scale processing by the private sector also needs to be studied. This effort should be supported by appropriate socio-economic and policy research, particularly to define the scale and layout of the milkshed, the efficiency of the existing marketing system and the relative economics of dairy versus other enterprises in different locations away from Kathmandu.

Although detailed information on the consumption pattern of meat is not available, there is evidence that about 100,000–300,000 small ruminants are imported from China and India. The domestic supply is inadequate because research efforts with small ruminants have been ineffective and incentives to increase production are virtually non-existent.

Institutions

Extension and most research activities are conducted under the Ministry of Agriculture, but links between research and extension remain weak. In the late 1980s, research was made more independent by creating the Nepal Agricultural Research Council (NARC) which, if anything, reduced the formal opportunities for joint planning and co-ordination. In the past, NARC was involved mainly in structural and administrative functions but, recently, some emphasis is being given to identify and formulate research priorities. The national research system is organised into departments and commodity programmes, supported by a network of experiment stations and farms. The National Rice Improvement Programme within the ministry had an outreach section to undertake on-farm testing of improved technologies in collaboration with extension staff. Other commodity programmes had similar outreach activities. However, this was replaced by the Cropping Systems Programme (1977–85) which had a link with the Asian Rice Farming Systems Network sponsored by the International Rice Research Institute (IRRI). This programme achieved some success in the Tarai region to disseminate the improved rice technologies, but little could be done in the hill regions mainly due to accessibility. In 1985, the Cropping Systems Programme was changed to a Farming Systems Division with a wider mandate, although the primary focus of research and extension remained with crop improvement. Socio-economic research was an integral part of the programme, but a separate Socio-Economic Research and Extension Division was created with the Farming Systems Division. The result was that the link between socio-economic research and both technology research and extension became weak at the national level. This division has conducted little research and primarily provides support to the ministry for compilation of statistics and formulation of projects.

Lumle Agriculture Research Centre and Pakhribas Agricultural Research Centre were established in 1968 and 1973, respectively, in different areas of the hill regions with United Kingdom government funding to support the resettlement of Gurkhas returning from the British Army. Both centres organised on-station and on-farm research and also developed their own extension activities to serve specific target areas. Later, these areas were expanded and services were provided to all types of farmers in the mandated areas. Recently, the centres have been incorporated into the national research system. Both centres have some staff, trained in systems research particularly in the crop sciences. Recently, the centres have reorganised their research programmes into multi-disciplinary teams and projects. Although both centres have a mandate for livestock research, it has received less attention than crops. Both centres have social scientists in the multi-disciplinary teams but, so far, they have concentrated their efforts more on crop-related research. There is a widespread belief that research results from India are especially applicable to Nepal, and there has been a tendency to draw on these experiences through study visits to the country.

Pakistan

Environment and cropping systems

Pakistan is located between latitudes 23°N and 36°N, and has a total land area of 79.6 million hectares of which 21.6 million hectares are cultivated; and 17 million hectares are irrigated. The country is divided into 4 provinces (Punjab, Sindh, Balochistan and North West Frontier), and 10 agro-ecological zones (AEZs) on the bases of climate, rainfall, temperature and potential land use (Cheema et al 1995). These are the Indus Delta, the Southern Irrigated Plains, the Sandy Deserts, the Northern Irrigated Plains, the Barani (rainfed) Areas, the Wet Mountains, the Northern Dry Mountains, the Western Dry Mountains, the Dry Western Plateau and the Sulaiman Piedmont. However, these AEZs can be grouped into four regions, namely the Dry Region (the Northern Dry Mountains, Western Dry Mountains, Dry Western Plateau and Sulaiman Piedmont), the Irrigated Region (Indus Delta, Southern Irrigated Plains and Northern Irrigated Plains), the Barani Region (Barani Areas and Wet Mountains) and the Sandy Desert Region (Thar and Cholistan deserts in north-east Sindh and southern Punjab provinces). Soils in the dry region are textually clays, calcereous loams and silty loams; in the irrigated region clays, silts, clay loams and sandy loams; and in the Barani region silty loams and silty clays (ADB 1989). Cheema et al (1995) described seven climates within the Alpine, Mediterranean, subtropical and tropical zones. Rainfall in Pakistan varies from 200 mm on the Balochistan Plateau to over 1200 mm in the Barani areas.

As in the Indo-Gangetic plain of India rice–wheat systems predominate, and there is no tradition of aquaculture associated with the systems as in South-East Asia. In most systems vegetables and fruits, particularly in Punjab Province, are grown along with the major crops (Tables A3 and A4).

Both irrigated and rainfed agriculture are practised. The primary source of irrigation is from an extensive canal system (70%) with the remaining 30% from tube-wells and wells. The Indus River Basin provides most of the water for canal irrigation and is the largest contiguous irrigation system in the world. The summer monsoon (July–August) and winter rains (January–February) provide additional water. Crops are grown in the summer (*kharif*) and winter (*rabi*) seasons, and cropping is divided arbitrarily into rice-based and non-rice-based systems.

In Sindh Province, some 65% of the land area is rangeland and non-rice-based systems predominate (85–90%) in the cropping areas. Irrigated agriculture is important except in the Thar desert, Cholistan and those areas inundated by the Indus River. In Punjab Province (27°N to 34°N latitude) some 47% of the land area is rangeland, and 25% of the total cropped area occurs on the Pothowar Plateau. Some 66% of croplands are irrigated. On the Pothowar Plateau, rainfall ranges from <500 mm to 1250 mm annually and temperatures from below freezing point in winter to 45°C in summer. The soils are mainly loams with texture varying from sandy to clay. Farms are <5.0 ha in

Table A3. *Major crops grown in the four provinces of Pakistan.*

Province	Irrigated		Non-irrigated	
	Summer	Winter	Summer	Winter
Sindh	In rice-based systems: rice, sugar-cane, cotton	Chick-pea, wheat	Pearl millet, sorghum inter-cropped with cowpea, water melon	Chick-peas in areas inundated in summer by the River Indus. Also, some mustard/ rapeseed
	In non rice-based systems: pearl millet, sorghum, sugar-cane, cotton	Wheat, chick-pea, mungbean, mustard, rapeseed		
Punjab	In rice-based systems: rice only	Wheat, peas, lentils, chick-pea, brassicas	In Thar desert: mono-crop chick-pea with some wheat in valleys	On Pothowar Plateau wheat, chick-peas, mustard/rapeseed inter-cropped with wheat for fodder, some lentils and grass beans
	In non-rice-based systems: sugar-cane, cotton, maize, sunflower		On Pothowar Plateau: forage sorghum and groundnut, some maize, water melon, pearl millet	
Balochistan	In rice-based systems: rice only In non-rice-based systems: sorghum, pearl millet, maize, mungbeans	Wheat, barley, chick-pea, oilseeds, some potato	Almost exclusively rangelands	
North West Frontier	In north: sugar-cane, sugar beet, maize	Wheat, oilseeds	Rice, maize inter-cropped with peas or beans	Peas and some potato
	In south: sugar-cane, rice, mungbean	Wheat, chick-pea, oilseeds		Chick-pea

Table A4. *Some important cropping patterns on the Pothowar Plateau, Punjab Province.*

Close to villages (considerable manure use)				Away from villages (little manure use)			
Year 1		Year 2		Year 1		Year 2	
Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Wheat	Maize	Wheat	Maize	Wheat	Sorghum	Fallow	Fallow
Wheat	Sorghum	Wheat	Sorghum	Wheat	Pulses	Fallow	Fallow
Wheat	Pulses	Wheat	Pulses	Wheat	Groundnut	Fallow	Fallow
				Wheat	Fallow	Wheat	Fallow

size; wheat and maize are the main subsistence crops and groundnuts and melons the main cash crops (Ministry of Agriculture 1997). Some important cropping systems on the Pothowar Plateau are presented in Table A5. The area of fallow land in Punjab Province is 1.18 million hectares out of a total area of 5.4 million hectares for the country as a whole. In Balochistan Province, some 93% of the land is rangeland. Of the 35.7 million hectares of land, only 1.7 million hectares are available for cultivation and only 50% of this is actually cultivated, mostly under irrigation. Below 2000 m altitude maize, rice, potato, wheat and barley are the main crops. Above this altitude, maize, wheat and barley are the most important crops. In the North West Frontier Province (NWF), 55% of the land is rangeland. Below 2000 m altitude, a double-cropping system is practised with maize and wheat as the main crops in summer and winter, respectively. Above this altitude, a single cropping system of either wheat or maize is practised.

Table A5. *Total areas of the major crops in each province (ha×10⁶).*

	Provinces			
Crops	Punjab	Sindh	NWF[1]	Balochistan
Wheat	5.8	1.08	0.85	0.33
Rice	1.27	0.65	0.06	0.12
Sugar-cane	0.55	0.26	0.1	-[2]
Cotton	2.27	0.49	-[2]	-[2]
Pulses	1.11	0.21	0.13	0.03
Rapeseed	0.14	0.08	0.04	0.04
Vegetables	0.12	0.03	0.04	0.03
Fruits	0.31	0.08	0.03	0.08

1. NWF = North West Frontier Province.
2. Area <5000 ha.

In the irrigated areas, especially in the provinces of Punjab and Sindh, salinity and waterlogging are increasingly becoming constraints to crop production. There are some 6.2 million hectares of saline and sodic soils in Pakistan and 11.4 million hectares of waterlogged soils. In mildly affected areas, yields of wheat, rice, sugar-cane and cotton have been reduced by 59–68%.

The fodder resources have been reported by Bhatti and Khan (1996). Some 65% of the country is covered by rangelands which occur from sea level to over 4000 m altitude. Approximately 2.7 million hectares annually are sown to fodder crops mostly in the irrigated systems. The traditional fodder crops are maize, sorghum and pearl millet in summer and berseem, alfalfa, oats, barley and mustard in winter. Chopped sugar-cane tops are also fed during the year. Over 500 exotic and indigenous forage species have been evaluated in Pakistan. In the Punjab Province, for example, Italian ryegrass, cowpea and Napier grass cv. Mott are showing promise in trials. In saline areas, accessions of saltbush (*Atriplex* species) are being tested to improve degraded lands. The highest priorities for commodity research are shown in Table A6.

Animal genetic resources

The 1997 livestock census recorded 20.7 million buffalo, 17.9 million cattle, 30.5 million sheep, 47.6 million goats and 380 million poultry. Biodiversity is reflected in the number of indigenous breeds that include four for the buffalo, 11 for cattle, 39 for sheep and 34 for goats. However, there has been serious genetic erosion within the indigenous breeds through indiscriminate crossbreeding. Limited and incomplete studies exist on the characterisation of breeds within species. The most serious loss of biodiversity is with cattle due to excessive and uncontrolled crossbreeding with Holstein–Friesian and Jersey blood. A recent survey of pure Sahiwal cattle in 12 out of 16 districts in Punjab Province shows that, while official statistics report a population of 100,000 animals, only about 5700 animals actually exist.

Table A6. *Main commodity research priorities by province in Pakistan.*

Provinces			
Punjab	Sindh	NWF[1]	Balochistan
Wheat	Rice	Wheat/maize	Apples
Cotton	Rape/mustard	Fruits/vegetables	Forages
Rice	Berseem	Oilseeds	Wheat

1. NWF = North West Frontier Province.

Buffalo are concentrated mainly in the Punjab (71.0%) and Sindh (20.5%) provinces. This species, mainly the dairy type, is becoming increasingly important, and this is reflected in a contribution of about 70% to total milk production. Buffalo are increasing in numbers at an annual rate of about 2.4% compared with 0.7% for cattle. As a consequence, in the Punjab and Sindh provinces buffalo are replacing cattle. Within these provinces, buffalo are found mainly in the irrigated areas where intensive crop cultivation is practised and, to a lesser extent, in the Barani (rainfed) areas where they are owned by smallholders, landless farmers and absentee landlords. The average smallholder owns five to eight buffalo which are used to produce milk for the urban market. The outstanding indigenous breed of buffalo is the Nili-Ravi.

Cattle are found mainly in the Punjab (50.3%) and Sindh (22.1%) provinces where they are used for milk production and draft power. The most important breeds are the Sahiwal and Red Sindhi for milk production and the Lohani and Kankrej for draft power. The Cholistani and Dhanni are dual-purpose breeds. The current breeding policy is aimed at using the Jersey in the Barani areas and the larger Holstein-Friesian in the irrigated areas where feed is more plentiful. Crossbreeding is common and these exotic breeds are used to improve 'nondescript' indigenous cows for milk production. Government policy now forbids crossbreeding with either the Sahiwal or Red Sindhi cattle. Discussions in the country suggest that there are about one million crossbred cattle in the country. Smallholders tend to use both crossbred cattle and buffalo for milk production, and are increasingly demanding higher levels of exotic blood in their cattle even though their management practices are inadequate.

Sheep are found mainly in Balochistan (47.7%), followed by Punjab (28.7%), Sindh (11.2%) and NWF (9.6%) provinces. Goats by comparison, are found mainly in Punjab (35.9%), followed by Balochistan (24.4%), Sindh (22.6%) and NWF (14.0%) provinces. Both species are kept by poor smallholders and landless farmers for whom these species are important for survival.

Animal production systems

Integrated crop-animal systems are very common especially in the irrigated areas where cultivation is intensive. Buffalo and cattle are used for milk production and cattle for land preparation and haulage. Animals are usually stall-fed in systems that use rice straw, seasonal green fodder and concentrates such as rice bran and cottonseed cake. Milk is sold directly by farmers or to middlemen who transport the milk to urban areas or processing units. Government provides artificial insemination services and those related to the animal health needs of the farmer. A major problem in these dairy farms is the lack of appropriate quality bulls for milk production and the availability of replacements for breeding. Currently, females are kept as replacements, but the males are disposed of without being selected for breeding. Dairy production is expanding rapidly due to the increased demand for milk in areas where there are organised milk marketing facilities and incentives/services to farmers are provided.

Commercial peri-urban and urban dairying is growing rapidly around the main cities such as Karachi, Lahore, Rawalpindi and Islamabad. A notable example of this is the Landhi cattle colony in east Karachi which has about 220,000 animals in a 5 km radius. About 95% of these animals are buffalo and 5% cattle; about half of the cattle are crossbreds. It began originally as a mechanism to concentrate animals outside the city limits, but this has now grown into a large and complex enterprise within the city. Pregnant animals are purchased from rural areas. After calving, female calves are sold except for a small number kept as replacements for breeding while male calves are fattened for 9 months and then slaughtered. At the end of their lactations, females are also slaughtered. Indiscriminate growth of the colony, without government supervision, has resulted in very complex and problematic situation that is made more complex by very poor hygiene from ever-increasing quantities of unused manure and its impact on the environment.

Small ruminants are associated with extensive nomadic and transhumant systems in the drier areas. The owners are mainly landless individuals, and flocks sizes are typically 40–120 head. Animals graze the poor grasslands over distances of 6–12 km/day. Crop stubble is also grazed. In return, shepherds are paid crop residues or cash for penning the sheep and goats in the fields to return manure and urine and thus improve soil fertility. Sheep are kept mainly for mutton production and goats for meat and milk. The rangelands of Balochistan Province are being degraded by overstocking and overgrazing and the removal of trees for fuel. The extensive systems are extremely complex, and are associated with authoritarian and hierarchical political structures in which the welfare of both livestock and people are central. In addition, open borders with neighbouring countries such as Afghanistan have allowed migration of people and animals resulting in random crossbreeding and disease transmission in the livestock. Resolving these problems involves several factors including land tenure and common property issues, improved services (e.g. animal health) and improved marketing of livestock and livestock products.

Poultry production is an advanced commercial industry based mainly on imported hybrids and technologies from developed countries. The industry is very specialised and is supported by several feed-milling plants, organised marketing outlets and strong private sector support. By comparison, the village scavenger systems are also important but remain largely neglected. Dual-purpose breeds are used for both meat and eggs, and this subsector makes a significant contribution to food security in the rural communities.

Feed resources

The total availability of feed resources in Pakistan is estimated at 93 million tonnes. Crop residues contribute 46%, grazing 27%, cultivated fodder 19%, cereal/legume grains and by-products 6% and the remainder comes from oilseed cakes/meals and feeds from animal sources. Estimates of supply/demand of nutrients seem to indicate a deficit of crude protein and energy for optimal outputs of milk and meat from the existing ruminant livestock. There is a growing trend towards the establishment of more intensive dairy cattle and buffalo production systems in peri-urban and urban areas, with increasing use of agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR).

The contribution of crop residues is likely to increase because of the higher priority given to cereal grain production. Wheat and rice contribute 52.5% and 22%, respectively, to the estimated 40 to 50 million tonnes of crop residues produced annually in Pakistan. Barley and oat straw and other crop residues are produced in smaller quantities. Traditionally, cereal straws are fed to cattle and buffalo year around, but their proportion in the ration increases during periods of feed shortages. Due to poor application of technology and weak extension services, farmers do not commonly practice chemical treatment of straw.

In Punjab Province crop residues are used for livestock feed, bedding, mulch, paper manufacturing and fuel. Wheat (54%), sugar-cane tops (29.5%) and rice straw (6.1%) constitute the bulk of the crop residues available. In Punjab and Sindh provinces, crop residues constitute 46% of the total diet of large ruminants. During the dry season they are often the only roughages available for livestock feeding. The feed resources in Punjab Province have been described and discussed by Pasha (1997).

Grazing lands include all categories of land that are not under forest or cultivation. Rangelands provide 60% of the feed requirements for sheep and goats. Average yields of dry matter range from 3.0 t/ha in the fallow lands to 0.5 t/ha in wastelands. In most areas grazing pressure is high. Carrying capacities in terms of sheep equivalents in different parts of the country are 0.3, 0.1, 2.8, 0.3 and 3.6 ha in NWF, Punjab, Sindh and Balochistan provinces and Azad Kashmir, respectively. The carrying capacity ranges from 0.6–2, 1–8, 1–8, 1.5–2.0 and 1.0 ha/ewe in NWF, Punjab, Sindh and Balochistan provinces and Azad Kashmir, respectively.

Major summer (*kharif*) fodders include maize, sorghum and millet cultivated alone or with cowpeas. Winter (*rabi*) fodders include berseem, oats and lucerne. Cultivated fodders are used for stall-feeding and may include rapeseed, barley and sometimes wheat. Green fodder is scarce during the dry seasons of May–July and November–December. Sugar-cane cultivation supplies 13.3 million tonnes of tops. Depending on the market price, whole sugar-cane may be fed to lactating cattle and buffalo.

Of the total cultivated area, only 15% is used for fodder production. Despite more than 60% increases in the ruminant population during the past 20 years, the total land devoted to fodder crops has declined by about 17%, with a corresponding increase in land used for production of food grain. This has further increased the dependence of livestock on crop residues and AIBP. In recent years, farmers have shown increasing interest in cultivating high-yielding fodder varieties such as Napier grass and Gamba grass (*Andropogon gayanus*). Fodder conservation through silage or haymaking is not practised.

Punjab Province produces 78% of the total fodder crops in Pakistan, followed by Sindh, NWF and Balochistan provinces, which produce 14.5%, 5.0% and 2.5%, respectively. The most commonly cultivated fodders during the summer season include maize, sorghum, millet and cowpeas. During the winter period fodders include oats, berseem, sugar-cane tops, barley, turnips and lucerne. In Sindh Province green fodder is produced on irrigated lands through the River Indus canal system.

Fodder trees and shrubs also contribute to the overall feed supply, particularly in hilly areas. The most common fodder trees are *Acacia modesta*, *A. nilotica*, *Zizyphus jujuba*, *Melia azadirachta*, *Z. numularia* and *Albizia procera*.

The major supplementary feeds in Pakistan are by-products from cereal milling (wheat/rice bran and rice polishings) and oilseed production (cottonseed cake, rapeseed cake, maize oil cake, sesame cake, linseed cake, rapeseed cake, mustard cake, groundnut cake and safflower cake). The by-products from cereal milling account for 75% of the total quantity of feeds used. By-products of animal origin play a minor role. The major by-products of the sugar industry are molasses, beet pulp and bagasse. More than one million tonnes of molasses are produced annually, however, its use in animal rations is limited, mainly due to alternative uses for distilling and export, and difficulties in transport and storage. The introduction and adoption of the urea–molasses block is limited to drier areas and sugarbeet pulp is available in the NWF. The country has 251 poultry feed mills, but only 5 produce compound feeds for ruminants. Generally, farmers use single protein sources or mix the concentrate ingredients themselves.

Fruit (citrus and banana) and vegetable wastes are also used for animal feed. Animal wastes (poultry excreta and feather meal) represent a vast reservoir of cheap nutrients for ruminant feeding. However, the cost of these wastes for ruminant feeds could increase significantly if proper treatment and quality control measures are adopted.

Animal health

Infectious, parasitic and metabolic diseases are common in livestock and cause heavy losses through mortality and morbidity. The overall loss due to diseases is estimated at about Rs. 8 billion/year (approximately US$ 200 million). Diseases are considered to be the second most important constraint to livestock production after feed resources.

Foot-and-mouth disease is the most important viral disease of cattle and buffalo in terms of morbidity and productive losses. Haemorrhagic septicaemia is the most important bacterial disease in these species. Mastitis and abortion are the third and fourth most important diseases in terms of economic losses; black quarter is endemic in hilly areas. Theileriosis and babesiosis are important diseases caused by blood parasites, especially in exotic and crossbred cattle. Fasciolasis, caused by *Fasciola hepatica* and *F. gigantica*, is the most important helminth disease in buffalo, cattle and sheep.

In sheep and goats, enterotoxaemia is the most important disease. Other important diseases of small ruminants include contagious caprine pleuropneumonia and helminthosis. Bluetongue in sheep in the NWF and peste des petits ruminants (PPR) in goats have gained significance in recent years. Warble fly infestation in goats and cattle causes huge losses through emaciation and skin/hide damage.

The extension services are primarily responsible for disease control and prevention through an extensive network of veterinary hospitals and centres. All provinces have disease diagnostic laboratories at the district level, but they lack facilities and trained manpower. Veterinary research institutes are engaged mainly with vaccine production. Research on different aspects of animal diseases is conducted at the agricultural universities, at veterinary research institutes and at the Pakistan Agricultural Research Council (PARC) in Islamabad. Facilities also exist for bacterial and viral isolation and serological work while expertise and facilities are lacking in toxicology and molecular biology. The vaccines produced in the country are deficient in quality and quantity. In most cases, the immunity lasts for six months or less, particularly for foot-and-mouth disease and enterotoxaemia, and vaccination covers only about 10% of the livestock population.

The research priority in animal health is to develop vaccines against various diseases. The research is at different stages of advancement:

- The major types of foot-and-mouth disease virus have been identified, but training and facilities for subtyping are lacking. There is a need to develop a more effective vaccine that includes all the types and subtypes of the virus.
- The different viral strains of bluetongue need to be identified and a vaccine against the disease developed.
- An effective PPR vaccine needs to be developed.
- The vaccine being produced for haemorrhagic septicaemia in Lahore, Peshawar and Quetta is of poor quality; there is a need for an improved vaccine.
- The vaccine being produced for enterotoxaemia lacks effectiveness because all types of the causative agent are not included.
- Brucellosis is the main cause of abortion in buffalo, cattle and goats and its frequency is increasing. Culling infected animals has been used as a means of control but this has not been effective. There is a need to develop an effective vaccine against this disease.

Socio-economics and policy

The livestock subsector is a significant component of agriculture, contributing 8.3% to the total GDP (PARC 1997) and is increasing annually. The National Commission on Agriculture wrote

By comparison to the major crops, the attention given to this sub-sector (i.e. livestock) is minimal and does in no way reflect the contribution which this sub-sector makes to the agricultural economy. The statistical information is weak and sometimes non-existent, policies pursued are designed to promote crop production and tend at the same time to be hampering rather than stimulating livestock production. There is a comparatively weak institutional framework to promote livestock development. Meeting the challenge of modernising the livestock sector requires a change of attitude towards this sector and an active policy for its development, reflected in appropriate allocations and institutional facilities (Government of Pakistan 1988). (This situation remains virtually the same to this day.)

The neglect of the sector is rooted in two quite different factors. First, elections in Pakistan may be won or lost on food grain availability and prices. Therefore, increased food production through huge public investment and policy support (e.g. incentives and subsidised inputs) remained a priority for successive governments. Coincidentally, political power is also controlled by rich absentee landlords and the emerging business class who are primarily interested in crops. However, 80% of the livestock are owned by powerless smallholders and the landless. The value of milk produced makes it the number one commodity in the country, but only 20–25% of milk output enters the market. Consequently, milk producers are not as powerful a group as the rice, wheat or cotton producers in influencing government policy. The second reason for the plight of the livestock subsector is the failure of the scientific community to act as an agent of change and development. Research, education and extension capacities for livestock have been built at huge public costs, although such investments are insignificant compared with those for crops. Inadequate collaboration and co-operation amongst tightly compartmentalised professionals, without any social accountability, have failed to provide the necessary technology and policy support through research.

The most visible change in animal production is the emergence of peri-urban and urban dairy production systems. These systems provide backward linkages to the rural areas for feeds and breeding stock and forward linkages to the urban areas for milk, meat and some concentrate feeds. Absence of rural infrastructure to support commercial dairy is by default pushing dairy production near urban areas where the market lies. A major negative effect of this is that manure is not ploughed back to the rural areas, and creates serious environmental and public health hazards. Furthermore, the failure to use manure represents a major waste of nutrients that could otherwise be used for crop production. This system is also likely to lead to inefficient use of scarce concentrate feeds as transportation of roughages is becoming costlier with expansion of peri-urban and urban dairies. With the high density of animals in small areas and improper management practices, the incidence of diseases is high and their management is becoming increasingly difficult.

There appears to be no clear policy goal for the livestock subsector, although government intervention can be seen in two main ways. First, there is direct involvement in production and processing activities through establishment of stock farms, processing plants, research and extension agencies, and vaccine production facilities. Second, the government provides veterinary drugs and services, artificial insemination, extension services and credit.

These public enterprises and interventions suffer from the common problem of economic, financial and managerial inefficiency and their failure to serve the intended beneficiaries (Faruque et al 1995). For example, several large dairy processing plants were established to collect and process rural milk, but without a proper road network and other supporting infrastructure. These large-scale enterprises were run initially at a loss and then were forced to close down their operations.

Current vaccine production provides for 2–26% of the demand for different diseases and it is not clear whether the most economically important diseases are the focus of such limited effort. PARC has sponsored an epidemiology project for several years, and the Government of Punjab also conducted an epidemiological study in that province, but there has been no objective assessment of disease priorities. A pilot study has been conducted (with support from the Asian Development

Bank) to assess the feasibility of privatisation of some aspects of veterinary delivery services. The results of this project are still awaited (Government of Punjab 1996a; Government of Punjab 1996b). There is a defined breeding policy which now emphasises selection and upgrading of buffalo breeds through progeny testing; upgrading of 'nondescript' draft cattle breeds for dairy production through crossbreeding with exotic animals; and prohibition of crossbreeding with Red Sindhi and Sahiwal cattle.

Government regulatory interventions in the livestock subsector have changed over time with the gradual liberalisation of the economy. However, the status of the current form of regulatory measures and their impact on the incentive or disincentive for investment in the livestock subsector is unclear. Given the general openness of the economy, the comparative advantage of livestock versus other agricultural activities and the scope for regional trade in various livestock products and live animals need to be investigated.

Institutions

Research on livestock in Pakistan is associated with institutes that are spread across all the provinces under the Livestock Directorates and with the three agricultural universities. Much of the research is supported and co-ordinated by PARC under the Ministry of Food and Agriculture. The provincial governments also have direct bilateral support from external funding agencies.

There are three aspects of research on livestock that are conspicuous. First, the process of research , taking into account national and provincial goals and needs of farmers, is extremely weak. Research priorities exist at the provincial level, e.g. in Punjab Province (Government of Punjab 1996c), but these appear to be based on economic indicators and the perceptions of scientists. Second, the responsibility for using resources is spread across several agencies. For example, rangeland development is the responsibility of the Forestry Department, research on livestock the responsibility of the Directorate of Livestock and Dairy Development (Research), and fodder production the responsibility of the Department of Agriculture. There is very limited co-ordination between these groups. Third, strong institutional and disciplinary compartmentalisation exists in which there is little or no collaboration within and between institutes. Teaching of veterinary and animal sciences is the responsibility of the Ministry of Education. The net result of these circumstances is that research prioritisation is extremely weak, unfocused, unco-ordinated, and diffused into a series of activities that lack integration and hardly address the needs of clients. The problem is further exacerbated by technology having to be delivered through an extension service that lacks effectiveness. The rift between veterinary medicine and animal production in the country is not healthy and does not serve to promote livestock development.

Sri Lanka

Environment and cropping systems

Sri Lanka is located in the Indian Ocean between latitudes 6°N and 10°N. The country has been divided traditionally into three major areas based on elevation, viz. the lowlands (<500 m), the midlands (500–1000 m) and the uplands (1000–2500 m). Rainfall in these areas is determined by two monsoons that blow seasonally from the south-west and north-east. The annual rainfall in the wet zone is >2500 mm, in the intermediate zone 2000–2500 mm, and in the dry zone <2000mm. Some areas in the north and east have an extended dry period between April and September. On the basis of the rainfall and elevation characteristics, nine agro-ecological zones (AEZs) are identified. However, these have been further subdivided on the basis of soil type into 24 AEZs (Ranawana and Perera 1995).

Rice is the major crop grown, and the three main export commodities are tea, rubber and coconut, grown mostly on large estates. The majority of smallholders integrate crops and livestock. In the uplands where tea is grown, small farmers combine dairy production with rainfed rice and a wide range of horticultural crops such as potato, chilli, cabbage, carrot, roots, beetroot and beans. Maize, sweet potato, bananas and avocado are also grown. Planting of improved grasses along contour bunds is practised and *Gliricidia sepium* is the main multi-purpose tree. Cropping is equally diverse in the intermediate and wet zones of the lowlands, where coconut and rubber predominate. Small farmers grow oranges, avocado, mango, bananas and vegetables (beans, chilli and pumpkin). Dairy animals are kept and small areas of pasture and *Gliricidia sepium* are planted under coconut. The Kandy Forest Gardens system has evolved over generations in the hills around the city. This very intensive agroforestry system combines natural forest and multi-purpose trees with fruits, coconut, vegetables, spices, flowers and small areas of improved pasture. The system is sustainable and impressive erosion control is practised through terracing. Farmers operating this system also grow rice in small plots in the valleys. In the dry zone of the lowlands, cropping is affected by the unreliability of rainfall. Both irrigated and rainfed agriculture is practised in this zone. Rice is important in the wet season and maize, chilli and potato are also planted. In the dry season onions are grown. Shifting cultivation based on maize and pumpkins is also practised on a small scale in some areas.

Animal genetic resources

Sri Lanka is endowed with a range of animal resources that include buffalo (for draft and meat), cattle (for milk), goats, sheep and non-ruminants. These are raised mainly by smallholders. Buffalo and cattle are found in the lowlands, although buffalo is more common in the midlands. Small ruminants are distributed in all AEZs, but are concentrated in the drier parts of the coconut growing areas. Research and development is facilitated by 31 farms belonging to the National Livestock Development Board (NLDB) covering an estimated 17,000 ha of land throughout the country. Twenty-four of these farms raise about 90% of the buffalo (swamp type), which are used for draft power mainly in rice cultivation in the lowland wet and dry zones. In the south-eastern part of the country buffalo are also milked. Several dairy crossbreeding programmes have been undertaken with buffalo dairy breeds from India. Cattle are of the indigenous zebu type and Holstein–Friesian crossbreds. With the increased demand for milk, crossbreds are becoming more important.

Goats and sheep are found mainly in the dry zones. Meat production is a priority although goats are also milked. Several Indian breeds such as the Jamnapari, Beetal and Madras Red have been introduced. More recently, the Boer breed has been used to produce crossbred goats for meat and milk.

Animal production systems

Animals are integrated with crops across all the AEZs. Cattle and buffalo are especially valued for draft power and haulage and for manure production. The animals subsist mainly on crop residues. More than 95% of the cattle and buffalo, 80% of the goats, and 76% of the pigs are kept by smallholders on farms of 0.5–2.0 ha in size (Ranawana and Pereira 1995).

Intensive dairy production based on Holstein–Friesian crossbreds is expanding around the Colombo and Kandy areas. In the Kandy area, dairy production is integrated with cropping in the Kandy Forest Garden system. Dairying is common among 20% of the farmers in this area, and dairy cattle contribute as much as 55% to total farm income. In the uplands, particularly on the tea estates, intensive dairy production systems are common, based on both crossbreds and pure exotic cattle.

In the rainfed lowland and upland areas, especially in the coconut zone, small ruminants are distributed widely and make a valuable contribution to total farm income, food security and poverty alleviation.

Feed resources

About 70% of the total livestock population is confined to the dry and intermediate zones of the country. Available feeds in these zones are low in quality and supply is seasonal. Fluctuating feed supplies are a major problem limiting dairy and small ruminant production. Native pasture is estimated to contribute more than 90% to total pasture production. Grazing lands are diminishing as small-scale farmers prefer to cultivate short-duration cash crops that are easily marketed and generate high incomes.

The major crop residue available is rice straw. However, out of the estimated 4 million tonnes produced annually, about only 50% is used as animal feed. Apparently, this low utilisation is due to a lack of awareness of its potential value as livestock feed. Sugar-cane tops contribute 13% to the total crop residues fed. In spite of significant research efforts, adoption of urea treatment of rice straw by smallholders is very low due to low delivery systems. However, urea–molasses blocks are gaining in popularity. Other cereal and pulse straws represent about 8% of the total feed available.

Multi-purpose tree species play an important role in integrated farming systems in Sri Lanka (Perera 1995). Multi-purpose trees fed to ruminant livestock, especially in the midlands and uplands, include *Erythrina variegata, Gliricidia sepium, Albizia falcataria, Tithonia diversifolia, Leucaena leucocephala, Samanea saman, Enterolobium saman* and *Artocarpus heterophyllus*. The most extensively used species is *Gliricidia sepium*. During the dry season, this species is utilised to supplement rice straw in the diet of large ruminants.

Agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR) alleviate feed deficits and lower the cost of milk production and other livestock products. It appears that AIBP (e.g. copra cake) are underutilised due to poor recovery and/or export. The utilisation of brewers grains is confined to the uplands where it is produced. NCFR include a range of valuable feeds such as the skins, pulp and seeds from the fruit canning industry.

In the midlands roadsides, riverbanks and uncultivable terrain are grazed communally and the grazing is controlled. Most animals are fed concentrates such as copra cake and rice bran. Farmers in the Forest Gardens system feed copra cake, grasses cut from the edges of cultivated plots, *Gliricidia sepium*, sunflower and hibiscus/jackfruit leaves to dairy cows. In the coconut areas the main sources of feed are rice straw, rice bran, copra cake, native grasses, *Gliricidia sepium* and, occasionally, improved grasses. Goats are grazed and fed *Gliricidia sepium*, copra cake, rice bran and jackfruit leaves.

Forage production in pine plantations involving the establishment of *Paspalum*, *Chloris gayana* and *Centrosema pubescens* could have potential for goat production. Pastures in coconut plantations also offer an important opportunity for livestock integration. Currently, only 20% of this land is exploited for grazing. Grasses successfully tested in coconut smallholdings include species of *Brachiaria, Setaria, Paspalum* and *Panicum*. It seems more difficult to graze in rubber plantations, however, cut-and-carry systems could be developed for these plantations.

Animal health

The main diseases are foot-and-mouth, haemorrhagic septicaemia and brucellosis. A number of studies have been undertaken on their epidemiology. Helminth parasites are also common. The priorities for animal health research are (a) to develop systems for livestock disease reporting, monitoring, surveillance and forecasting (computer models need to be developed for use in strategic planning aimed at cost effective disease control); (b) to control diseases through the use of disease tolerant breeds, improved nutrition and management; (c) to conduct studies on foot-and-mouth disease, haemorrhagic septicaemia, black-quarter, mastitis, brucellosis, enterotoxaemia, cerebrospinal nematodiasis and diseases caused by fungal and plant toxins; (d) to undertake fundamental studies on the factors affecting host and drug resistance for parasitic diseases; (e) to conduct fundamental studies on the biological factors associated with zoonotic diseases; and (f) to produce vaccines through biotechnology.

Socio-economics and policy

Sri Lanka has had a liberal economic policy since the early 1980s. Restrictions on international trade have been gradually lifted, investment in the private sector has been made easier, and some major public sector enterprises have been privatised. These general policy changes affected the livestock subsector adversely because no specific policy goal has been pursued and the liberalisation has not been extended fully to the subsector. For example, as a result of market liberalisation self-sufficiency in dairy products decreased from about 80% in the early 1980s to 20% at present. With no physical restriction on imports and elimination of tariffs, imported products have flooded the market. However, government-owned livestock and dairy farms have not changed their status and have continued to function inefficiently at a loss. Crossbreeding has been used as the main mechanism to improve dairy production, but the programme has been pursued without a national breeding policy. These farms have been compelled to sell milk to government-owned processing plants and a multinational company at unattractive prices fixed by the government, which is a contradiction of the liberal market policy. The processing plants have also been compelled to collect milk from smallholder producers using prices fixed by the government, which are low compared with prices in the open market. The dairy marketing infrastructure (collection points and chilling and processing capacity) is inadequate, and there is a large spread between the farm and retail prices of milk. Supply and delivery of inputs (feeds, artificial insemination and health care) continue to be poorly managed by government agencies. Consequently, both dairy and meat production have not responded adequately to the open-market policies. An additional problem is that, as the economy has continued to grow, rural wage rates have increased due to labour shortages, and the cost of feeds and feed ingredients have also increased. Consequently, the competitive advantage of dairying and other livestock enterprises has decreased.

Traditional livestock production and consumption remain stratified along religious and ethnic lines. The Buddhists consume little meat, particularly beef and fresh milk, but they do drink yoghurt. These differences may change if there are economic incentives to pursue specific production enterprises for the market. There is no evidence that any promotional and incentive structure has been used to encourage livestock and dairy production across religious and ethnic groups.

Little socio-economic and policy research has been conducted to support desired policy and institutional changes in the livestock subsector. In 1996, the Sri Lankan Council for Agricultural Research Policy (CARP) funded 1258 research projects in various institutions. Of these, only 23 (1.9%) were on animal production and health and 69 (5.7%) were on economics, development and sociology. None of the latter were related to livestock. There was only one on farming systems with livestock as a component. At the Postgraduate Institute of Agriculture in Peradeniya University, none out of 11 MSc/PhD topics in economics in 1997 was concerned with livestock.

Institutions

At least three ministries are responsible for crop, livestock, fisheries and plantation agriculture (tea, rubber and coconut). Each ministry has its relevant research institution. CARP is the apex body for co-ordination of agricultural research conducted by various ministries and their affiliated research institutions and universities. CARP is attached to the Ministry of Agriculture but has little executive power to influence the research agendas of individual research institutions, as CARP is only one of several sources of research funds.

The Natural Resources, Energy and Science Authority (NARESA), under the Ministry of Science and Technology, also funds a small number of agricultural and animal science research projects. The Veterinary Research Institute (VRI) is the only livestock research institute in the country. It conducts both animal health and production research; it is perhaps stronger in health research. Over half of the resources of the VRI are devoted to providing diagnostic and laboratory services, and vaccine production for the Department of Animal Health and Production. The Faculty of Veterinary Medicine and the Department of Animal Science in the Faculty of Agriculture of Peradeniya University conduct research at MSc and PhD levels with funds received from various sources including CARP and NARESA. However, linkages between the VRI and the university are weak.

Both the VRI and the university follow a disciplinary approach to research. Collaboration amongst scientists of different disciplines is minimal, and many aspects of research are often duplicated in disciplinary experiments. However, there is an awareness that research needs to focus on a systems approach to make research results useful to clients. Past research has generated many technologies which have not been adopted because potential users and technology-transfer agencies were not involved in the research process.

Appendix II

Itinerary of research team

India

12 October 1997		Team arrive at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, Andhra Pradesh, India.
13–14 October 1997		ICRISAT, Hyderabad. Finalisation of plans for mission and initiation of literature review.
15 October 1997	am	Visit to the Indian Council for Agricultural Research–National Academy of Agricultural Research Management (ICAR-NAARM) for discussions with staff.
	pm	Visit to College of Veterinary Science, Acharya NG Ranga Agricultural University, Hyderabad for discussions with staff and farm visit.
16 October 1997	am	Visit to Indo-Swiss Project, Hyderabad for discussions. Depart Hyderabad for Pune, Maharashtra by air.
	pm	Visit to Bharatiya Agro-Industries Foundation (BAIF) Central Research Station and farms at Urulikanchen, near Pune; discussions with staff.
17 October 1997	am	Continued discussions with BAIF staff. Depart Pune by road for Mumbai.
	pm	Arrive Mumbai and depart by air to Hyderabad.
18 October 1997		Visit with Indo-Swiss Project staff to farms at Kondareddypally, and to Milk Chilling Centre, Kalwakurthy near Hyderabad.
19 October 1997		Depart Hyderabad for New Delhi by air.
20 October 1997	am	ICAR Headquarters, New Delhi. Discussions with Deputy Director General (Animal Sciences) and Assistant Directors General (Animal Production and Breeding, Animal Nutrition and Physiology and Animal Health).
	pm	Continued discussions at ICAR. Meeting with National Resources Adviser, British Development Corporation Office, New Delhi.
21 October 1997	am	New Delhi to Karnal, Haryana by road. Visit to ICAR National Dairy Research Institute (NDRI).
	pm	Discussions with Director and Division Heads. Visit to Farming Systems Research Project, Sxamag, Shanigarh, Dadupur.
22 October 1997		Karnal to Pantnagar, Uttar Pradesh by road
23 October 1997	am	Visit to G.B. Pant University of Agriculture and Technology, Pantnagar. Visit to field and campus of Agriculture and Veterinary Sciences Faculties. Discussions with staff.
	pm	Pantnagar to Izatnagar by road. Meeting with Director General and Director of Research of ICAR-Indian Veterinary Research Institute (IVRI), Izatnagar.
24 October 1997	am	Visit to IVRI facilities and discussions with heads of divisions
	pm	Visit to farm in Purenatal village.
25 October 1997	am	Izatnagar to Makhdoom by road.

	pm	Visit to ICAR-Central Institute for Research on Goats (CIRG), Mahkdoom. Discussions with staff and visit to research farm.
26 October 1997	am	Field visit at CIRG.
	pm	Depart Mahkdoom for New Delhi by road
27 October 1997		Depart New Delhi for Colombo, Sri Lanka by air.

Sri Lanka

27 October 1997	am	Arrive Colombo, Sri Lanka by air.
	pm	Meeting with Executive Director, Sri Lanka Council for Agricultural Research Policy (CARP), Colombo.
28 October 1997	am	Meeting with Secretary, Director of Planning and Livestock Adviser, Ministry of Livestock Development and Estate Infrastructure, Colombo.
		Meeting with Director General, Natural Resources, Energy and Science Authority of Sri Lanka (NARESA), Colombo.
	pm	Visit to National Livestock Development Board (NLDP), Colombo. Discussions with Chairman, Assistant General Manager and other staff.
		Depart Colombo for Kandy by road.
29 October 1997	am	Visit to Director, Postgraduate Institute of Agriculture, University of Peradeniya, Kandy.
		Visit to Dean, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Kandy.
		Visit to Director, Department of Animal Production and Health, Ministry of Livestock Development and Rural Industries, Kandy. Discussions with Director and five Heads of Divisions.
	pm	Visit to Veterinary Research Institute (VRI), Department of Animal Production and Health, Ministry of Livestock Development and Rural Industries, Kandy. Discussions with staff.
30 October 1997		Visit to small farms in the Hill Country/Up-Country Tea Zone, east of Kandy in the Central Province.
31 October 1997	am	Workshop on research priorities with staff of Department of Animal Production and Health, Ministry of Livestock Development and Rural Industries, and University of Peradeniya, Kandy.
	pm	Free.
01 November 1997		Visit to small farms in Coconut Triangle near Kandy and Dry Zone of Low Country, north of Kandy.
02 November 1997	am	Visit to Farm Gardens System, Kandy.
	pm	Kandy to Colombo by road. Colombo to New Delhi, India by air.

Nepal

03 November 1997	am	New Delhi to Kathmandu, Nepal by air.
	pm	Meeting with Secretary, Ministry of Agriculture, Kathmandu.

04 November 1997	am	Kathmandu to Bandipur by road. Visit to Agricultural Research Station (Goats), Bandipur.
	pm	Bandipur to Pokhara by road. Arrive Lumle Agricultural Research Centre (LARC).
05 November 1997	am	LARC. Meeting with staff.
		Visit Livestock Development Farm, Department of Livestock Services, Ministry of Agriculture, Pokhara.
	pm	Pokhara to Kathmandu by road.
06 November 1997	am	Arrive Kathmandu. Meeting with Director General and staff of Department of Livestock Services, Ministry of Agriculture. Visit to National Animal Science Research Institute, Nepal Agricultural Research Council (NARC).
	pm	Round-up meeting with Executive Director, Director of Livestock and Fisheries Research and staff of NARC.
		Mission team departs for home

Pakistan

12 January 1998	am	Arrive Islamabad, Pakistan by air (DT and MJ). Other team members (CD and EZ) arrived earlier.
	pm	Meeting with Chairman and staff of Pakistan Agricultural Research Council (PARC), Islamabad.
13 January 1998		Visit to National Agricultural Research Centre, PARC, Islamabad. Discussions with Director and staff.
14 January 1998	am	Depart Islamabad by air for Karachi (Sindh Province).
	pm	Visit to Landhi Milk Colony, East Karachi.
15 January 1998	am	Depart Karachi by road for Hyderabad.
	pm	Visit to Sindh Province Department of Animal Husbandry. Discussions with Director and staff.
16 January 1998	am	Visit to Science Complex, Department of Livestock and Fisheries (Sindh Province), Korangi, Karachi. Visit to Poultry Vaccine Production Centre at Complex. Discussions with Director and staff.
	pm	Courtesy visit to Secretary, Livestock and Fisheries Department for Sindh Province.
17 January 1998	am	Depart Karachi by air for Lahore (Punjab Province).
	pm	Visit to Veterinary Research Institute, Lahore. Discussions with Director.
18 January 1998	am	Depart Lahore by road for Bahadurnagar.
	pm	Visit to Livestock Production Research Institute and small farms, Bahadurnagar. Discussions with Director and staff.
19 January 1998	am	Visit to Research Institute for Physiology of Animal Reproduction, Bhunirey.
		Visit to Halla Milk project, Pattoki. Discussions with Area Development Manager and Senior Veterinary Manager. Visit to milk processing plant.
	pm	Depart Pattoki by road for Faisalabad.

20 January 1998	am	Visit to University of Agriculture, Faisalabad. Meetings with Vice-Chancellor, Director of Research, Deans of Departments of Veterinary Science and Animal Husbandry, Chairmen and Professors of Departments.
	pm	Depart Faisalabad by road for Lahore.
21 January 1998	am	Visit to Director General (Extension), Livestock and Dairy Development (Punjab Province), Lahore.
		Visit to College of Veterinary Science, Lahore. Meetings with Principal, Chairmen and Professors of Departments. Visit to college facilities.
	pm	Meeting with fodder expert from FAO Integrated Range/Livestock Development Project in Baluchistan. Discussions on livestock and range issues in Baluchistan.
22 January 1998	am	Round-up meeting with PARC Animal Health Specialist accompanying mission.
	pm	Depart Lahore by air for New Delhi, India.

India

23 January 1998		Preparation of draft report for Pakistan.
		Visit of CD and EZ to ICAR for discussions with senior staff.
24 January 1998	am	Meeting of mission team to discuss Pakistan report.
	pm	Depart New Delhi by air for Calcutta.
25 January 1998	am	Depart Calcutta by air for Paro, Bhutan.

Bhutan

25 January 1998	am	Arrive at Paro, Bhutan by air.
	pm	Paro to Thimpu by road. Initial discussions with Research Co-ordinator, Research-Extension-Irrigation Division (REID), Ministry of Agriculture, Thimpu.
26 January 1998	am	Meetings with Acting Director, Research Co-ordinator of REID, Chief Animal Production Officer (Crop and Livestock Services Division) and Head of Planning and Policy Division, Ministry of Agriculture, Thimpu.
	pm	Visit to Veterinary Epidemiology Centre, Serbithang, near Thimpu.
27 January 1998	am	CD and DT depart Thimpu for Paro by road. Depart by air from Paro to Calcutta, India. MJ remains in Thimpu until 29.01.98.
	pm	Preparation of report on Bhutan.
27 January 1998	am	MJ visits National Artificial Insemination Centre, near Thimpu.
	pm	Visit to smallholder dairy farms; Renewable Natural Resources Research Centre, Yusifong; and FAO Office, Thimpu (MJ).
28 January 1998	am	MJ visits Planning and Policy Division, Marketing Section, Thimpu.
	pm	MJ departs Paro by air for Dhaka, Bangladesh. CD and DT depart Calcutta for Bangalore by air.

29 January 1998		CD and DT visit the ICAR-National Institute for Animal Nutrition and Physiology, Bangalore, India. Discussions with Director and staff. Visit to facilities.
30 January 1998	am	Bangalore to New Delhi by air (CD and DT).
	pm	New Delhi to Dhaka, Bangladesh by air (CD and DT).

Bangladesh

31 January 1998– 01 February 1998		Editing of country reports.
02 February 1998	am	Visit to Bangladesh Agricultural Research Council (BARC), Dhaka. Discussions with Executive Chairman, Members of BARC for Livestock, Crops, Farming Systems.
		Visit to Department of Livestock Services (DLS), Ministry of Fisheries and Livestock. Discussions with Director General and staff members.
		Visit to Livestock Research Institute, DLS. Discussions with Director of Research.
	pm	Visit to Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka. Discussions with Director General, Heads of Divisions and other staff.
03 February 1998	am	Visit to Bangladesh Milk Producers Cooperative Union Ltd. Dhaka. Discussions with General Manager, Deputy General Manager and Assistant General Manager.
		Visit to Bangladesh Agricultural Research Institute (BARI), Gazipur. Discussions with Director General and staff of On-farm Research Division.
	pm	Visit to Bangladesh Rice Research Institute (BRRI), Gazipur. Discussions with Director General, Director of Research and Head of the Rice Farming Systems Programme.
04 February 1998	am	Dhaka to Mymensingh by road. Visit to Bangladesh Agricultural University (BAU). Discussions with Vice-Chancellor; Deans of Faculties of Animal Husbandry, Agricultural Economics and Veterinary Science; Director of Bangladesh Agricultural University Research System (BAURES) and Professors of Departments.
	pm	Visit to farms in UK-funded project with BAU on introduction of legumes into rice-based systems (DT). Further discussions with staff (MJ and CD). Mymensingh to Dhaka by road.
05 February 1998	am	Visit to Bangladesh Rural Advancement Committee (BRAC), Dhaka. Meeting with Programme Manager and Poultry/Livestock Specialist.
		Visit to Grameen Bank and Grameen Motsho Foundation (GMF), Dhaka. Meeting with Managing Director of GMF.
	pm	Visit to British High Commission, Dhaka. Meeting with First Secretary (Natural Resources).
		Round-up meeting at BARC, Dhaka with 50 livestock scientists from institutions visited. Depart Dhaka for New Delhi, India (CD).

06 February 1998	am	Visit to Planning Commission, Government of Bangladesh, Dhaka. Discussions with Member for the General Economics Division; Chief, Agriculture Division and Chief, Livestock Section (DT and MJ).
	pm	Depart by air for home (DT and MJ).
06 February 1998		Visit to Central Leather Research Institute (CLRI), Chennai, India (CD).
07 February 1998	am	Depart by air for home (CD).
18 February - 07 March 1998		Preparation of mission report at ICRISAT, Hyderabad,
01-02 March 1998		Visit National Dairy Development Board (NDDB), Anand (CD).
07 March 1998		Team members leave for home.

Appendix III

List of persons met

A Bangladesh

Bangladesh Agricultural Research Council, Dhaka

1. Dr Z. Karim, Executive Chairman
2. Dr G.M. Shahjahan, Member-Director (Livestock)
3. Dr M. Altaf Hossain, Member-Director (Agric. Economics and Rural Sociology)
4. Dr M.A. Razzaque, Chief Scientific Officer (Crops)
5. Dr M.A. Razzaque, National Coordinator, Farming Systems Research Programme

Department of Livestock Services, Dhaka

6. Dr K.A. Fattah, Director General
7. Dr M.H. Siddiqui, Assistant Director, Animal Health Division
8. Dr A. Rahman, Director, Smallholder Livestock Project
9. Dr M. Hossain, Director, Livestock Research Institute

Bangladesh Livestock Research Institute, Savar

10. Dr Q.M.E. Haque, Director General
11. Dr M.S. Uddin, Animal Scientist
12. Dr K.S. Huque, Animal Scientist
13. Dr S.M.A. Rahman, Agricultural Economist
14. Dr M. Islam, Head, Farming Systems Division

Bangladesh Milk Producers' Co-operative Union Ltd. (Milk Vita), Dhaka

15. Mr G.C. Shaha, General Manager
16. Dr M.A. Barik, Deputy General Manager
17. Mr S.A.M. Anwarul Haque, Assistant General Manager

Bangladesh Agricultural Research Institute, Gazipur

18. Dr M.A. Mazed, Director General
19. Dr M.A. Maleque, Director (Training)
20. Mr N.K. Shaha, Principal Scientific Officer
21. Mr M. Fazul Haq, Head, On-farm Research Division (OFRD)

22. Dr M. Ahmed, Senior Scientific Officer, OFRD
23. Dr M.S. Hossain, Head, Agricultural Economics Division

Bangladesh Rice Research Institute, Gazipur

24. Dr M.A. Hamid Mia, Director General
25. Dr A.N.M. Rezeal Karim, Director of Research
26. Dr Nur-e-Elahi, Head, Rice Farming Systems Research Division (RFSRD)
27. Mr M.R. Siddiqui, Economist, RFSRD

Bangladesh Agricultural University (BAU), Mymensingh

28. Prof M. Hussain, Vice-chancellor
29. Prof M. Karim, Director, BAU Research System
30. Prof M. Saadullah, Dean, Faculty of Animal Husbandry
31. Prof Q. Hasan, Dean, Faculty of Veterinary Sciences
32. Prof S.M. Bulbul, Poultry Science
33. Prof M. Ali Akbar, Animal Nutrition
34. Prof M.A. Mannau, Dairy Science
35. Prof M.L. Dewan, Veterinary Pathology
36. Prof I. Hossain, Agricultural Statistics
37. Prof M. Sirajul Islam, Agricultural Economics
38. Prof M.F. Alam, Agricultural Finance
39. Prof M.A. Hossain, Farming Systems and Environmental Studies Project
40. Prof H. Rahman, Dept. of Parasitology

Bangladesh Rural Advancement Committee, Dhaka

41. Mr M.A. Saleque, Manager, Employment and Income Generation Programme
42. Dr M.M. Rahman, Livestock Specialist

Grameen Bank and Grameen Motsho Foundation, Dhaka

43. Mr A.Z.M. Nasiruddin, Managing Director, Grameen Motsho Foundation

Bangladesh Planning Commission, Dhaka

44. Prof M. Lutfor Rahman, Member (General Economics Division)
45. Dr M. Sanaullah, Chief, Agriculture Division
46. Mr M.A. Sattar, Joint Chief, Livestock and Fisheries Section

British High Commission, Dhaka

47. Mr Tom Barrett, First Secretary, Natural Resources Adviser

B Bhutan

1. Mr S. Gyaltshen, Acting Director, Research, Extension and Irrigation Division (REID), Ministry of Agriculture (MOA)
2. Dr U. Tshewang, Research Programme Coordinator, REID
3. Mr P. Gyamstha, Co-ordinator, Renewable Natural Resource Research, REID
4. Dr P. Gyamtola, Head, Planning and Policy Division, MOA
5. Mr K. Wangdi, Chief Animal Production Officer, Crops and Livestock Services Division (CLSD), MOA
6. Mr T.N. Acharya, Assistant Animal Production Officer, CLSD, MOA
7. Dr P. Wangdi, CLSD, Royal Veterinary Epidemiology Centre
8. Mr P. Namgyel, Programme Co-ordinator for Forestry Research, REID, MOA
9. Ms S. Kobayashi, Programme Officer, Food and Agriculture Organization of the United Nations
10. Mr C. Dendup, Planning Officer, Planning and Policy Division, MOA

C India

Indian Council of Agricultural Research (ICAR), Delhi

1. Dr M.L. Madan, Deputy Director General, Animal Sciences
2. Dr A. Verma, Assistant Director General, Animal Nutrition
3. Dr Lal Krishna, Assistant Director General, Animal Health
4. Dr V.K. Taneja, Assistant Director General, Animal Production and Breeding
5. Dr D. Jha, Director, National Centre for Agricultural Economics and Policy

National Dairy Development Board (NDDB), Anand

6. Dr V. Kurien, Chairman
7. Dr A. Patel, Managing Director
8. Dr D.K. Singh, Head, Biotechnology Laboratory
9. Dr P.V. Pannikar, Manager, Technology Mission
10. Dr M.R. Garg, Scientist, Animal Nutrition and Feed Technology
11. Dr B.C. Varshney, Scientist, Animal Health
12. Mr B.K. Ganguli, Specialist, Sector Planning and Systems

National Academy for Agricultural Research Management, Hyderabad

13. Dr S.N. Saha, Joint Director
14. Dr P. Kumar, Head, Information and Communication Management Unit
15. Dr A. Maru, Senior Scientist, Information and Communication Management Unit
16. Dr P. Manikandan, Senior Scientist, Agricultural Research Systems and Policy Management
17. Dr B.S. Chandel, Senior Scientist, Economist, Agricultural Research Systems

Acharya N.G. Ranga Agricultural University, Hyderabad

18. Dr I.V. Subba Rao, Vice-Chancellor
19. Dr V. Jayarama Krishna, Dean, Veterinary College
20. Dr P. Raghavulu, Dean, Agriculture Faculty
21. Dr B. Yadagiri, Principal, Veterinary College

Indo-Swiss Project Andhra Pradesh, Hyderabad

22. Dr Venkateshwarlu, Veterinarian, Department of Animal Husbandry

Bharatiya Agro-Industries Foundation, Pune

23. Dr N.G. Hegde, President
24. Dr B.R. Mangurkar, Vice President
25. Dr A.L. Joshi, Programme Director
26. Dr R.K. Mahuli, Chief Programme Co-ordinator

National Dairy Research Institute, Karnal

27. Dr K. Singh, Director
28. Dr R.V. Singh, Head, Dairy Economics, Statistics and Management Division
29. Dr B.K. Joshi, Head, Dairy Cattle Breeding Division
30. Dr R.S. Ludri, Head, Dairy Cattle Physiology Division
31. Dr N. Balaraman, Head, Dairy Cattle Nutrition Division

G.B. Pant University of Agriculture and Technology, Pantnagar

32. Dr H. Singh, Dean, College of Veterinary Sciences
33. Dr S.P. Sharma, Professor, Head, Veterinary Medicine
34. Dr S.N. Maurya, Professor, Head, Gynecology and Obstetrics
35. Dr T.S. Boghul, Assistant Professor, Agricultural Economics
36. Dr A. Kumar, Assistant Professor, Animal Nutrition
37. Dr R.B. Prasad, Associate Professor, Genetics and Animal Breeding

Indian Veterinary Research Institute, Izatnagar

38. Dr O.S. Tomer, Director
39. Dr M.C. Prasad, Joint Director, Research
40. Dr C. Natarajan, Joint Director, Academic
41. Dr G. Butchaiah, Head, National Biotechnology Center
42. Dr S. Kumar, Head, Livestock Production Technology Division
43. Dr B.B. Mahapatra, Head, Physiology and Climatology Division
44. Dr R. Singh, Head, Livestock Economics and Statistics Division
45. Dr N.N. Patack, Head, Animal Nutrition Division
46. Dr M.H. Khan, Head, Parasitology Division
47. Dr L.N. Purve, Head, Animal Reproduction Division
48. Dr H.P.S. Arya, Head, Extension and Education Division
49. Dr S.P.S. Ahlawat, Head, Animal Genetics and Breeding Division

Central Institute for Research on Goats, Mathura

50. Dr A. Rekib, Director
51. Dr N. Singh, Head, Goat Health Division
52. Dr B.U. Khan, All India Project Co-ordinator on Goats
53. Dr S.K. Singh, Animal Breeder
54. Dr D.K. Nandi, Physiologist
55. Dr J. Misri, Pathologist
56. Dr S.C. Saxena, Animal Breeder
57. Dr K.P. Agarwal, Animal Nutritionist

National Institute of Animal Nutrition and Physiology, Bangalore

58. Dr K. Singh, Director
59. Dr P.V. Sarma, Senior Scientist
60. Dr K.T. Sampath, Senior Scientist, Nutrition
61. Dr K.S. Ramachandran, Senior Scientist, Nutrition
62. Dr K. Arthanatham, Senior Scientist, Agricultural Economics
63. Dr I.J. Reddy, Physiologist
64. Dr S.C. Roy, Biochemist

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru

65. Dr S. M. Barghouti, Director General

66. Dr F.R. Bidinger, Principal Scientist, Physiology
67. Dr R.J.K. Myers, Principal Scientist, Soil Fertility
68. Dr A. Hall, Socio-Economics and Policy Division
69. Dr P.P. Rao, Economist
70. Dr P.K. Joshi, Economist

D Nepal

1. Dr S.N. Upadhaya, Secretary, Ministry of Agriculture
2. Dr D. Joshi, Executive Director, Nepal Agricultural Research Council (NARC)
3. Dr S.B. Panday, Chief, Animal Nutrition Division, Animal Science Research Institute (ASRI), NARC
4. Dr U. Mishra, Director, Livestock and Fisheries Research, ASRI, NARC
5. Dr H.R. Shrestha, Animal Production Scientist, ASRI, NARC
6. Dr A. Pradhan, Animal Health Research Scientist, ASRI, NARC
7. Dr D. Pariyar, Head, Pasture and Fodder Research Division, ASRI, NARC
8. Dr N.P. Shresthra, Chief, Animal Breeding, NARC
9. Dr B.M. Shrestha, Director General, Department of Livestock Services (DLS)
10. Mr S.L. Pradhan, Deputy Director General, DLS
11. Dr S. K. Shakya, Chief, Livestock Production Division, DLS
12. Mr C.R. Upreti, Chief, Goat Research Station (GRS), Bandipur
13. Mr R.C. Khanal, Team leader, Livestock Feeds and Feeding Research, Lumle Agricultural Research Centre (LARC)
14. Dr R.P. Sah, Head, Technical Division, LARC
15. Dr D.P. Rasali, Senior Livestock Research Officer, LARC
16. Mr T.B. Gurung, Head, Socio-economics Division, LARC
17. Dr B.M. Shrestha, Director General, Third Livestock Project, DLS
18. Dr S.L. Pradhan, Deputy Director General, DLS

E Pakistan

Islamabad

1. Dr Z. Altaf, Chairman, Pakistan Agricultural Research Council (PARC)
2. Dr A.H. Cheema, Member (Livestock), PARC
3. Dr M. Akbar, Director General, National Agricultural Research Center (NARC)
4. Dr M. Asghan, Director, Rangeland Research Institute, NARC
5. Dr U.N. Khan, Director, Animal Production Institute, NARC

6. Dr A.G. Khan, Director, Animal Nutrition Institute, NARC
7. Dr M.F. Khan, National Project Director, Small Ruminants, NARC
8. Dr B.A. Malik, Director, Pulses, NARC
9. Dr M.M. Aziz, Director, Barani Livestock Production Research Institute, Kherimurat
10. Brig S.U. Cheema, Director General, Agency for Barani Area Development
11. Dr R. Ahmed, Director, Directorate for Livestock and Dairy Development and Extension

Sindh Province

12. Dr M.N. Baloch, Secretary to Government of Sindh, Karachi
13. Dr G. Hussain, Assistant Director, Animal Husbandry, Government of Sindh, Karachi
14. Dr B.M. Junejo, Director General, Livestock and Fisheries, Hyderabad
15. Dr G.B. Essani, Dean, Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agricultural University, Tando Jam
16. Dr H. Shaikh, Director, Red Sindhi Farm, Directorate for Dairy and Livestock Development, Hyderabad
17. Dr M.I. Khan, Director, Poultry Production and Research Institute, Karachi
18. Dr S. Rehmanji, Director, Sindh Poultry Vaccine Centre, Karachi

Punjab Province

19. Dr S.Z. Malik, Director General, Livestock and Dairy Development (Extension), Lahore
20. Dr M. Zulfiqar, Director, Veterinary Research Institute for Punjab, Lahore
21. Dr A.A. Ashger, Director, Livestock Production Research Institute (LPRI), Bahadurnagar
22. Dr M. Sharib, Deputy Director General, LPRI, Bahadurnagar
23. Dr I. Ali, Assistant Director, Research Institute for Physiology of Animal Reproduction, Bhunikey, Pattoke
24. Dr S. Saleem, Area Development Manager, Idhara-E-Kissan, Pattoki

University of Agriculture, Faisalabad

25. Prof A.N. Sheri, Vice Chancellor
26. Prof A.H. Gilani, Director of Research
27. Prof M.A. Sial, Dean, Faculty of Animal Husbandry
28. Prof S. Ali, Dean, Faculty of Veterinary Science
29. Dr B. Ahmed, Professor of Agricultural Economics

College of Veterinary Sciences, Lahore

30. Prof R.A. Chaudry, Principal
31. Prof N. Ahmad, Department of Animal Nutrition

32. Prof M.A. Munder, Department of Microbiology
33. Prof K. Pervez, Department of Veterinary Medicine
34. Prof M. Sabir, Department of Pharmacology
35. Prof A. Rabbani, Department of Parasitology
36. Prof. T.N. Pasha, Department of Animal Nutrition

FAO, Balochistan

37. Dr S.H. Hanjira, Fodder Expert, Integrated Range/Livestock Development in Balochistan

F Sri Lanka

Colombo

1. Dr D. Kirtisinghe, Executive Director, Sri Lanka Council for Agricultural Research Policy
2. Dr P. Ramanujam, Secretary, Ministry of Livestock Development and Estate Infrastructure (LDEI)
3. Dr R. Amarasekara, Director, LDEI
4. Dr S. Daniels, Director, Planning, LDEI
5. Prof (Mrs) P.E. Soysa, Director General, Natural Resources, Energy and Science Authority of Sri Lanka (NARESA)
6. Dr A.S. Eliatamby, Chairman, National Livestock Development Board (NLDB)
7. Dr N. Ranaweera, Additional Secretary, Ministry of Agriculture
8. Dr J.S. Punjrath, Managing Director, NDDB, Sri Lanka Dairy Ltd.

Kandy

9. Dr H.P.M. Gunasena, Director, Postgraduate Institute of Agriculture, University of Peradeniya, Kandy
10. Prof V.Y. Kuruwita, Dean, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya
11. Dr S.S.E. Ranawana, Director, Department of Animal Production and Health, Ministry of Livestock Development and Rural Industries (MLDRI)
12. Dr (Mrs) S. Kodituwakku, Deputy Director, Animal Health, MLDRI
13. Dr A.O. Kodituwakku, Deputy Director, Resource Management, MLDRI
14. Dr K.C. Somapala, Deputy Director, Livestock Resource Development, MLDRI
15. Mr A.P.W. Netlasinghe, Deputy Director, Human Resource Development, MLDRI
16. Dr S. Premaratne, Animal Nutrition, University of Peradeniya
17. Dr A.N.F. Perera, Animal Nutrition, University of Peradeniya
18. Dr D.D. Dissayake, Animal Production and Health, University of Peradeniya

19. Dr R. Wickramasinghe, Veterinary Research Institute (VRI)
20. Dr S.P. Gunaratne, Nutritionist, VRI
21. Dr T.G. Wijewardana, Bacteriologist, VRI
22. Dr S.R. Jayasinghe, Parasitologist, VRI
23. Dr P.G.S. Gunawardana, Pathologist, VRI
24. Dr I.K. Leukebandara, Farming Systems, VRI
25. Dr W.R.A.K. Rajapaksha, Breeder, VRI
26. Dr A.W. Kalupahana, Virologist, VRI

Appendix IV

List of acronyms

ADB	Asian Development Bank
AEZ	Agro-ecological zone
AIBP	Agro-industrial by-product
BARC	Bangladesh Agricultural Research Council
CGIAR	Consultative Group on International Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth disease
FSR	Farming systems research
GDP	Gross Domestic Product
ICAR	Indian Council of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
LGP	Length of growing period
NARC	Nepal Agricultural Research Council
NARS	National agricultural research systems
NCFR	Non-conventional feed resources
NDDB	National Dairy Development Board
NGO	Non-governmental organisations
PARC	Pakistan Agricultural Research Council
PPR	Pestes des petits ruminants
SAARC	South Asia Association for Regional Cooperation
TAC	Technical Advisory Committee