Livestock in Mixed Farming Systems in South Asia

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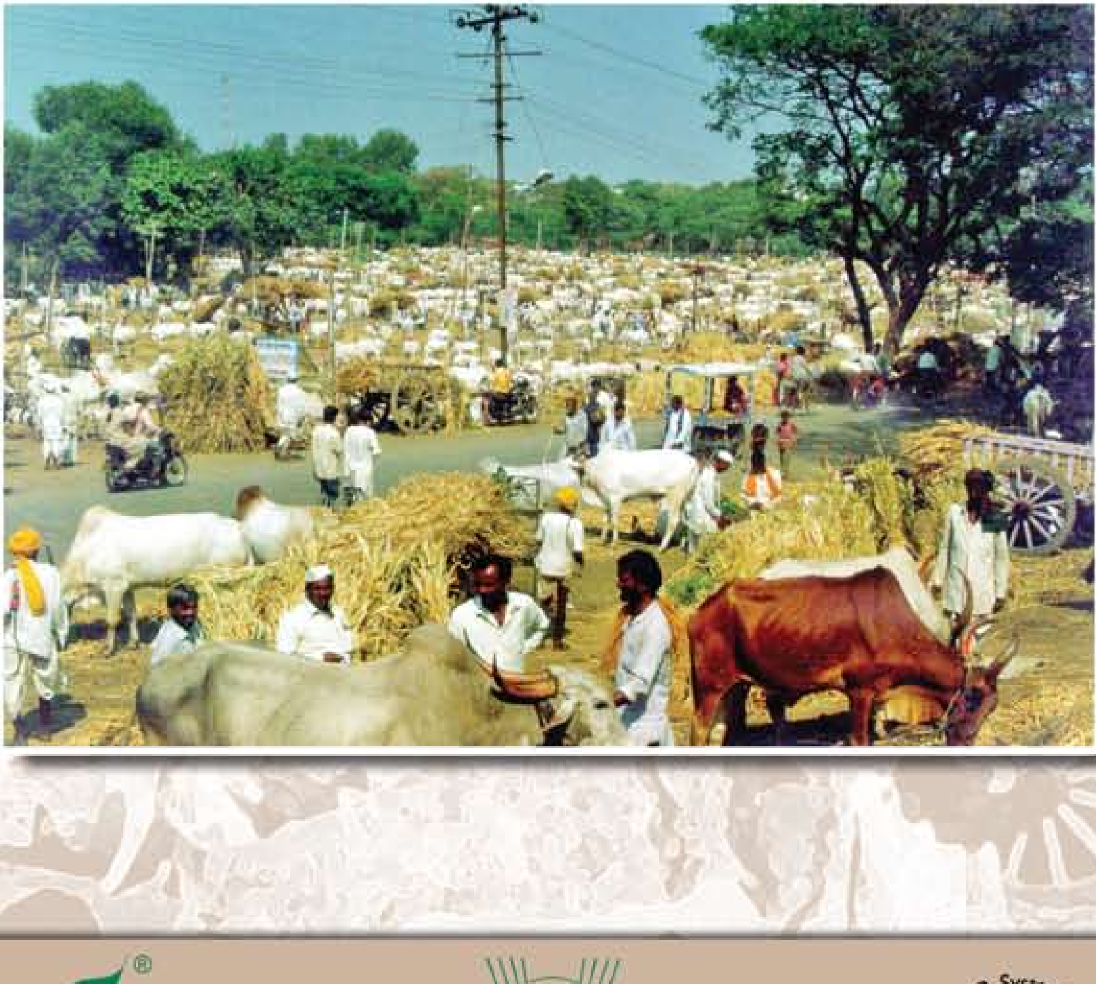

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Abstract

Animal production in South Asia is predominantly part of mixed crop-livestock farming systems vital for the security and survival of large numbers of poor people. In such systems, livestock generate cash income, provide draught power and manure, utilize crop residues and by-products making them partially, closed systems, and thus the most benign from the environmental perspective. Mixed farming systems however, are extremely complex and heterogeneous in terms of crops grown, livestock species raised and in their responses to development initiatives. Further, recent decades have seen significant changes in mixed systems in terms of livestock demography, increased commercialization (degree of integration with markets), etc. Factors contributing to this change include growing human population, mechanization of cultivation and rural transportation, use of inorganic fertilizers and government programs to promote animal production. On the demand side, an important factor contributing to the change has been the growing demand for livestock products (milk and meat) driven by income growth, urbanization and changes in tastes and preferences in the region. Meeting this growing demand is both an opportunity and a challenge for small-scale mixed crop-livestock farmers. Unlike in the past, productivity increases should contribute a larger share to output growth owing to increasing pressure on land and competing resources. Low productivity of livestock in mixed crop-livestock systems in South Asia is due to non-adoption of available technologies or their uptake has not been sustainable, because they were improperly targeted into the farming systems (for example, introducing cross-breeding technology in areas with poor feed resources, improved forage crops in low rainfall areas etc).

To better understand the nature of small scale mixed farming systems in South Asia, the recognition of the strong nexus between crop and animal production, the striking variation in systems and the need for differential intervention, a Crop–Livestock Systems typology has been constructed that delineates the regions of each country into homogenous crop-livestock zones /systems with similar response to technology uptake and development initiatives. Thus, the typology would enable better targeting of technical and socio-economic interventions aimed at improving animal productivity and protecting the natural resource base on the farms in South Asia.

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Foreword

Mixed crop-livestock systems are the dominant form of animal husbandry in South Asia supporting millions of smallholders in the region. This book highlights the importance of livestock for the poor in mixed crop-livestock systems, the role and importance of ruminant production, the vital inter-linkages between crop and animal production and changes in these systems over time. The growing demand for livestock products propelled by income growth, urbanization and changes in tastes and preferences presents an opportunity for smallholders in these systems to ride on the wave of the demand-led livestock revolution. However, there are concerns that liberalization and globalisation may undermine the competitiveness of these systems since productivity levels are abysmally low.

The impressive growth in livestock production (milk and meat) in South Asian countries in the last two decades was mainly driven by an increase in animal numbers. However, attempts at increasing productivity levels in the region have met with limited success. For instance, the numerous technologies developed related to improved breeds, animal nutrition and health have shown low and patchy adoption, as diverse and complex farming systems have been treated as a single homogenous system. Further, given the increasing pressure on land and other resources in the region, better targeting of technology and development initiatives becomes imperative to accelerate productivity-led growth.

To address these concerns a mixed Crop-Livestock Systems typology has been constructed for select countries in South Asia to better understand the nature of small-scale mixed farming systems, the strong nexus between crop and animal production, the striking variation among systems within a country, and the need for differential intervention in different systems. It is hoped that this typology will help in understanding the complex agro-ecological and socio-economic realities of mixed systems and will better inform research and policy design.

Though this highly informative book fills a large void in the literature, like all studies, it cannot address all the issues related to crop-livestock systems. Yet it serves as a crucial base from which others can build on its findings.

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Abbreviations

AI	Artificial Insemination
AIBPs	Agro-industrial By-products
ARPU	Agro-climatic Regional Planning Unit
BBS	Bangladesh Bureau of Statistics
CLS	Crop-Livestock Systems
CW	Culturable Wasteland
DAPH	Department of Animal Production and Health Administration
DCP	Digestible Crude Protein
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
GCA	Gross Cropped Area
GDP	Gross Domestic Product
GOI	Government of India
HP	Horse Power
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGFRI	Indian Grassland and Forage Research Institute
IGP	Indo-Gangetic Plains
LGP	Length of Growing Period
MDGs	Millennium Development Goals
MCLS	Mixed Crop Livestock Systems
NARC	Nepal Agricultural Research Council
NCAP	National Centre for Agricultural Economics and Policy Research
NCA	Net Cropped Area
OLS	Ordinary Least Squares

R&D	Research and Development
SMP	Skimmed Milk Powder
SURE	Seemingly Unrelated Regression Estimation
TDN	Total Digestible Nutrients
UMMB	Urea Molasses Mineral Block
VRI	Veterinary Research Institute
WDI	World Development Indicators
WMP	Whole Milk Powder
WTO	World Trade Organization

Chapter 1

Introduction

1.1. Rationale for this Study

Poverty is all pervasive in the developing world, where every fifth person subsists on less than $1 a day. The poor, however, are largely concentrated in sub-Saharan Africa (SSA) and South Asia, and account for 29% and 40% respectively of the total 1.1 billion poor in the world (World bank 2004). Poverty rates are also high; 46% of the population in sub-Saharan Africa and 31% in South Asia live below the poverty line. Since poverty deprives adequate access to food, an estimated one-third of the population in sub-Saharan Africa and one-fourth in South Asia suffer from undernutrition/malnutrition. Extricating these people out of the poverty trap remains a major concern of and challenge to the global community and national governments in these regions.

The Millennium Development Goals (MDGs) target the reduction of global poverty by half by 2015, from 28% in 1990. Progress has however been slow and varying across regions -- a drastic decline in East Asia & the Pacific region from 30–15% between 1990 and 2000 (WDI 2005), and a decline in South Asia to 31% in 2000, that translates into a reduction of 10 percentage points since 1990. The significant reduction in poverty in East Asia was engineered by a rapid economic growth of 7–10%. During the first five years of the 21st century, most South Asian economies witnessed almost similar growth. It is predicted that if these trends continue for another decade, these countries would be able to achieve the target of halving poverty by 2015 (Devarajan and Nabi 2006).

Most of the poor in developing countries live in rural areas. They depend on agriculture and allied activities for their livelihood. Thus a rapid growth in agriculture and rural development is crucial for reducing poverty. This has been clearly brought out in the literature on agriculture-poverty nexus (Ravallion and Datt 1996; Thirtle et al. 2003; Warr 2003 and World Bank 2005). In countries like Chile, Ghana, India, Thailand and Vietnam, agricultural growth has spurred overall economic growth and successfully reduced poverty. In fact, Ravallion and Datt in their study on India have shown that growth in the agricultural sector is more pro-poor than growth in other economic sectors such as industry and services. In much of the developing world, the rate of poverty reduction has been higher in countries that achieved higher growth in the agricultural sector (World Bank 2005).

Agricultural growth directly and indirectly contributes to poverty reduction. Improvements in production and productivity enhance farmers' incomes, create employment and income opportunities for landless laborers and bring down food prices, thereby improving the accessibility of the poor to cheaper food. Agricultural growth alone cannot reduce poverty; much depends on the societal distribution of the benefits of growth, which in turn is determined by the access to the poor of factors of production i.e., land, labor and capital. In most developing countries, land holdings are small and are highly unequally distributed. The incidence of landlessness is also quite high. For instance, in India 58% of rural households have land holdings of less than 2 ha with an average size of 0.6 ha (GOI 2006). Additionally, 32% of rural households do not have any access to land. Hence, from the perspective of poverty reduction it is important to identify agricultural activities that are accessible to the poor, are labor intensive, generate sufficient income and have enough potential for growth.

Livestock fit well in this scheme of poverty reduction. They play the role of enhancing livelihoods of the poor. About 70% of the rural poor in the developing world are associated with livestock production and they obtain a higher share of their income from it than do the rich (Delgado et al. 1999). Shukla and Brahmankar (1999) and Birthal et al. (2003) found landless and small farm households deriving a substantial proportion of their income from livestock. This is because livestock are more equitably distributed compared to land, especially in land-constrained developing countries. Growth in livestock production would therefore have a more favorable effect on poverty reduction than growth in crop production alone.

Livestock generate a continuous flow of income, enabling the poor to meet their daily cash requirements and other contingency expenditures. As a source of food, they contribute towards reducing malnutrition, particularly among children and lactating mothers. Delgado et al. (1999) found a negative relationship between per capita animal protein intake and incidence of undernourishment in developing countries. Livestock are natural capital assets with self-accumulative capability through reproduction. This implies that the greater the accumulation of livestock wealth, the greater is the flow of income. Livestock also act as a cushion against income shocks from crop failure and help consumption smoothening during times of crisis. Kurosaki (1995) found that diversification towards livestock contributed to the stabilization of poor household incomes, particularly during drought years. Further, livestock allow the poor to gain private benefits from Common Property Resources (CPRs).

In developing countries, income from livestock comprises nearly one-third of the agricultural income (FAOSTAT 2005). Since 1981, income from livestock in the developing world has grown at 4.7% a year, more than 1.5 times the growth in crop income. Between 1981 and 2003, per capita consumption of milk and meat in developing countries almost doubled. Most developing countries experienced rapid increases in per capita income and urban population during this period, which eventually translated into swift increases in demand for animal food products as compared to staples.

Similar trends have been observed in the livestock economy of South Asia, which are likely to continue on account of three major factors. First, current per capita consumption of animal food products is much less in the developing world than in the developed world. Second, the factors underlying demand growth in the recent past have been quite robust, and are unlikely to subside in the near future. Third, the proliferation of supermarkets provides easier access to ready-to-eat convenience animal-based foods. A substantial increase in demand for livestock food products is projected in developing countries over the next two decades (Delgado et al. 1999).

Increasing integration of global markets under the World Trade Organization (WTO) is opening up new opportunities for exports of animal-based food products. With the unfolding of globalization, trade in livestock products has almost doubled since 1991. In developing countries, the agricultural export structure has been slowly changing in favor of livestock products (Aksoy 2005). The share of dairy and meat products in agricultural exports of developing countries increased from 6.5% in 1991 to 8.5% in 2004. In some countries like India, the share of livestock products in agricultural exports almost doubled, from 3.3 to 6.6% during this period. Evidence suggests that though many developing countries are competitive in the production of livestock products, they tend to lose out in international markets because of highly inefficient processing and the huge protection given to the livestock sector in major exporting countries. With stringent food safety and quality standards prevailing in global trade, developing countries are hampered by their inability to comply due to high costs and poor infrastructure.

Opportunities thus exist for a demand-driven growth in the livestock sector in developing countries. However, the question remains as to how the poor can benefit given constraints such as lack of access to inputs, technology, credit, services and product markets. Livestock in most developing countries are raised as part of mixed farming systems and productivity is low. In the recent past, increase in livestock numbers has driven most of the growth in production, though this is not sustainable in the long run. Many developing countries, especially in Asia, have high livestock densities, which is a matter of concern from the point of environmental protection and human health. Growth in livestock production has to come from improvements in animal productivity through greater animal nutrition and health in the short to medium run and from genetic enhancement for superior breeds in the long run.

Mixed farming systems facilitate considerable synergy among the various system components, leading to a more efficient use of farm resources. Livestock provides draft power and manure for use in crop production, while agricultural residues and by-products are their main feed ingredients. Despite this, agricultural research and development strategies have often been pursued in a compartmentalized manner without taking into consideration the interactions between the crop and livestock sectors. Although there is much talk about farming systems research in developing countries, according to Thomas et al. (2002), "much of what is defined as farming systems research is nothing more than a series of studies on cropping patterns, which ignore the presence of livestock in the system. Animal science research too has tended to emphasize component technologies ignoring the nexus between crop and livestock sector".

A significant amount of work has been undertaken to delineate homogeneous agro-ecological zones and farming systems in South Asia, but these are mainly crop oriented (Sehgal et al. 1992; ARPU 1993; GOI 1989 and Scholz, 1987). What is needed is a clear picture of the characteristics of crop and animal production within mixed farming systems, and the way these systems are changing in different regions. There is a paucity of information on farming systems research that incorporates animals interactively with cropping systems.

1.2. Scope of the Study

Research, policies and institutional interventions will be more effective in promoting agricultural growth and consequently rural development and poverty reduction given:

- the recognition of the close synergy between crop and animal production;
- a better understanding of the distribution pattern of land and livestock across rural communities and their relative importance in enhancing livelihoods of the poor; and

- an appreciation of the complexities of mixed systems, and the need for customized interventions in different systems.

This book analyzes prevalent mixed farming systems in South Asia using a systems approach that incorporates interactions between crop and livestock sub-systems and the underlying agro-ecological and socio-economic conditions. Specifically, the focus is on providing:

- a comprehensive and integrated view of the dynamics of livestock production in South Asia and its role in poverty reduction;
- a typology of mixed crop-livestock farming systems for South Asian countries and its characteristics; and
- an understanding of the relative importance of agro-ecological, technological and socio-economic factors in influencing the intensification of systems, adoption of livestock technologies and productivity of the system.

The book is organized into 8 chapters[1]. The following chapter describes the importance of livestock in economic development and poverty alleviation in South Asia. A demand-supply analysis of animal-based food products in South Asia is undertaken in Chapter 3 to examine opportunities for growth in the livestock sector. Chapter 4 discusses the need for a crop-livestock typology and the methodology for its construction. Chapters 5 through 7 describe mixed Crop-Livestock Systems prevalent in India, Sri Lanka and Nepal and their characteristics. The concluding chapter identifies major R&D interventions in different Crop-Livestock Systems that can help improve overall system productivity.

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[1] This book is a synthesis of findings from an earlier project reported in 'Increasing Livestock Productivity in Mixed Crop-Livestock Systems in South Asia' (Parthasarathy Rao et al. 2004), workshop proceedings (Birthal and Parthasarathy Rao 2002 and ICRISAT 1999) and other relevant material compiled during the course of the project and compilation of the book.

Chapter 2

Livestock and the Poor

South Asia occupies 3.2% of the land area and supports 22% of the world population. One-third of its population is poor, 80% of which lives in rural areas (FAOSTAT 2005). A majority of rural poor are landless and small landholders. Crop production, livestock, wage labor and self-employment in small-scale non-farm enterprises are the main sources of livelihood. Fostering rapid growth in agriculture and allied sectors thus remains a major policy concern in countries of the region.

Livestock have been an integral part of the socio-economic fabric of rural life in South Asian countries, as a source of draft power, manure and food, albeit at subsistence levels. Besides, livestock perform insurance and banking functions. Recent evidence however indicates that the livestock sector is under transition from subsistence to commercial activity, and is now viewed as an important source of income, nutritional security and poverty reduction.

Rapid income growth and increasing urbanization are causing significant increases in demand for high-value food commodities, including milk, meat, eggs and fish (Kumar et al. 2003). This expanding demand serves as an opportunity for millions of rural poor in the region to augment incomes, as the distribution of livestock wealth is more equitable compared to land. Thus growth in livestock production is expected to be more pro-poor than a similar growth in crop production.

2.1. Livestock's Contribution to Income

Agriculture (including animal husbandry) remains the key economic sector in most South Asian countries (WDI 2005). Its share in gross domestic product (GDP) ranges from a high 39% in Nepal to a low 16% in Sri Lanka (Figure 2.1). In Bangladesh, India and Pakistan, it accounts for one-fifth to one-fourth of their GDP.

Consistent with the theory of economic development, there has been a decline in the share of agriculture in GDP everywhere in South Asia (Figure 2.1). Between 1980–82 and 2002–04 its share fell by 15 percentage points in India and 11 percentage points in Bangladesh, Nepal and Sri Lanka. The least decline of 6 percentage points was in Pakistan, where the share of agriculture in GDP in the 1980s was the lowest along with that in Sri Lanka.

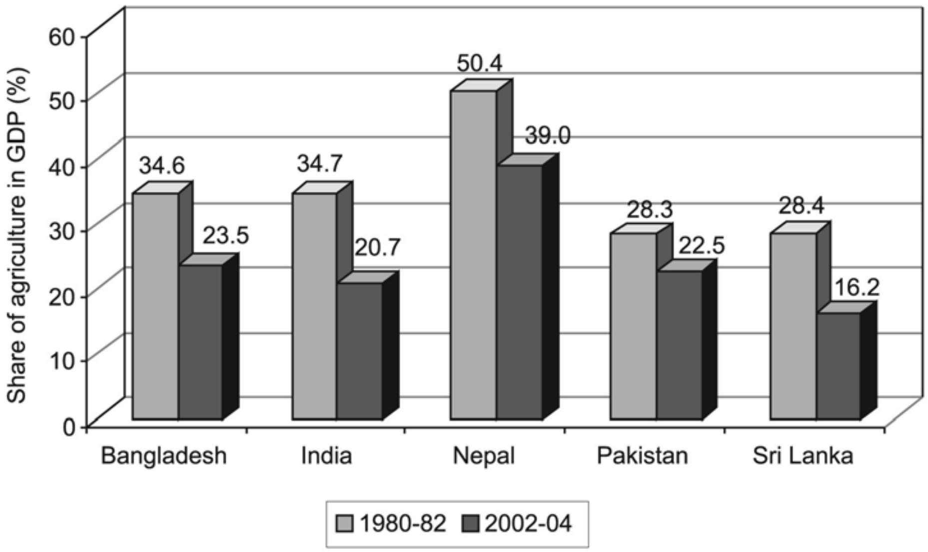

Figure 2.1. Share of agriculture (%) in the GDP of South Asia, 1980–82 and 2002–04.

The importance of agriculture, however, transcends its economic contribution. It is the lifeline of millions in the region and supports at least 53% of the population. However, the dependence on agriculture varies across the region -- it supports as much as 93% of the population in Nepal and between 45 and 53% in other countries (Figure 2.2).

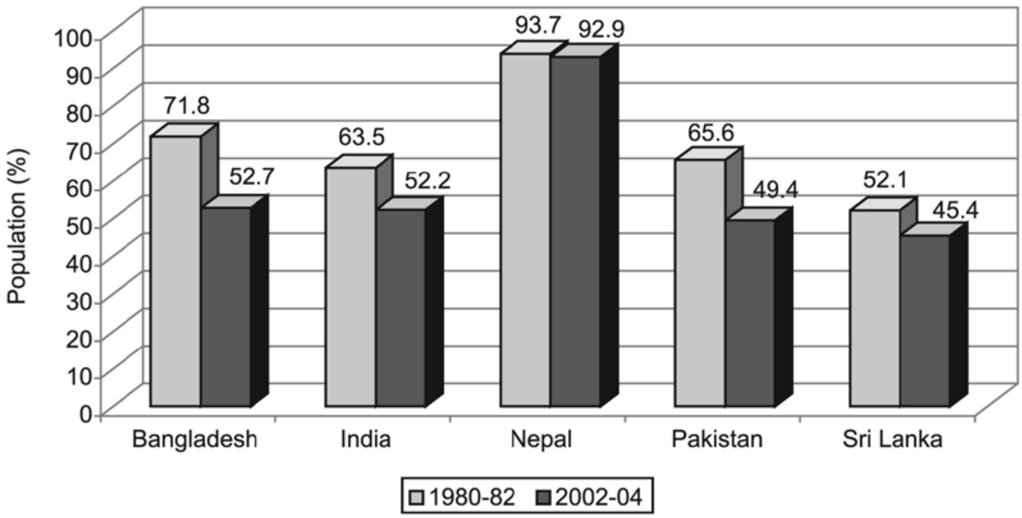

Figure 2.2. Share of population (%) dependent on agriculture in South Asia, 1980–82 and 2002–04.

While livelihood dependence on agriculture continues to be high, the scope for bringing additional land under cultivation is limited due to the increasing demand for land for non-agricultural purposes. Between 1980 and 2003, agricultural area in South Asia remained unchanged at 222 million ha, while agricultural population increased by 30%, from 580 million to 744 million. This translates into a decline in per capita agricultural land availability from 0.4 to 0.3 ha in the region. Across countries, per capita agricultural land is the lowest in Bangladesh (0.1 ha). This implies (i) growing pressure on land to produce food for a growing population; (ii) increasing stress on natural resources; and (iii) shrinking livelihood opportunities in crop production.

Diversification into activities such as livestock production that generate higher returns from lesser land and are labor-intensive is considered to be an important pathway to augment rural livelihoods.

The livestock sector contributes nearly one-third of the agricultural income in South Asia, compared to 47% in developed countries. Its share in agricultural income in South Asia has increased by 7 percentage points since 1980–82, with rapid increases expected in the years to come.

There is significant inter-country variation in the contribution of livestock to agricultural income (Figure 2.3). It is as high as 53% in Pakistan, as low as 12% in Bangladesh and 14% in Sri Lanka and a moderate 31% in India and 29% in Nepal. It may be noted that all the countries in the region except Nepal have shown an increase in the share of livestock in agricultural income in the last two decades.

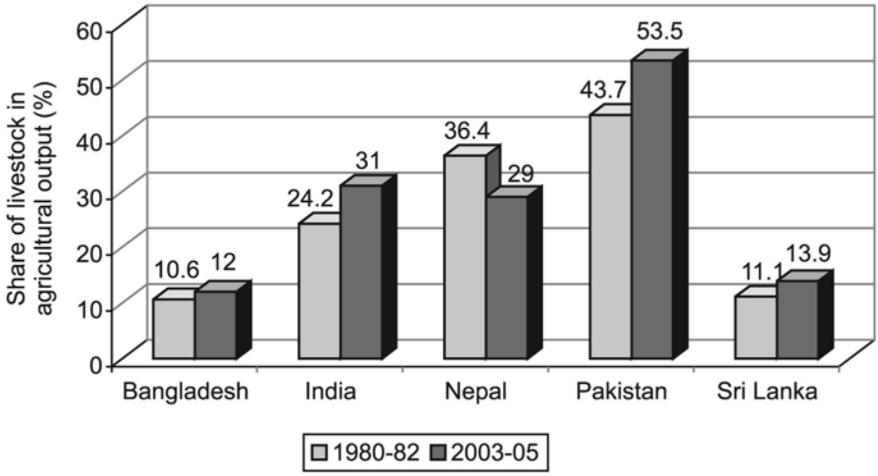

Figure 2.3. Share of livestock (%) in agricultural output in South Asia, 1980–82 and 2003–05.

2.2. Livestock and Poverty Reduction

Poverty is all pervasive in South Asia; despite this most countries in the region have made significant progress in poverty reduction over the last two decades (Table 2.1). India has done extremely well as the proportion of poor in the total population declined to 24% in 1999/2000 from 43% in 1983. Poverty declined in other countries too, but not as swiftly. The latest available poverty estimates vary across countries, nevertheless it was found that Nepal has the highest incidence (44%), followed by Bangladesh (40%), Sri Lanka (25%) and India (24%).

Table 2.1. Poverty in South Asia (% headcount).

Country	Period	Rural	Urban	Total
Bangladesh	1983-84	53.8	40.9	52.3
	2000	43.6	26.4	39.8
India	1983	61.1	35.7	43.0
	1999/2000	26.8	21.4	24.1
Nepal	1984-85	43.1	19.2	41.4
	1995-96	46.6	17.8	44.6
Pakistan	1984-85	49.3	38.2	49.3
	1998-99	35.9	24.2	32.6
Sri Lanka	1985-86	35.6	18.4	30.9
	1995-96	27.0	14.7	25.2

Source: Jayasuriya (2002).

Poverty in South Asia is largely a rural phenomenon with as much as 80% of the poor concentrated in rural areas. For instance, in Nepal 47% of the rural population is poor, as compared to 18% in urban areas. The difference in rural-urban poverty ratio is also higher in Bangladesh and Sri Lanka. Further, a majority of the rural poor in the region are landless and small farm households.

Significant reduction in poverty in the region over the last two decades was engineered by rapid and sustained economic growth. Since the early 1980s, GDP has been growing at over 5% a year. Per capita income growth, that was a mere 0.5% per annum during 1960–1980, accelerated to over 3% in the later years (Jayasuriya 2002).

Agriculture has played a key role in spurring economic growth and thereby in poverty reduction, especially rural poverty. Between 1981 and 2004, the agricultural sector grew at about 3% a year in South Asia (Table 2.2). Ravallion and Datt (1996); Hasan and Quibria (2002) and Warr (2003) have shown that growth in the agricultural sector is more pro-poor than growth in other economic sectors.

It is important to identify the components of agriculture with greater potential to reduce poverty. Table 2.2 presents growth rates in livestock vis-à-vis the crop sector in South Asian countries. On the whole, during the last two decades, livestock production in the region has grown at a rate of 4.1% a year compared to 2.5% in crop production. This pattern prevails throughout the region, except in Nepal. In Pakistan, the livestock sector grew at a healthy annual rate of about 5% and in India at 4%. The increasing share of livestock in agricultural growth implies that growth is potentially more pro-poor as livestock assets are more egalitarian compared to land.

Table 2.2. Annual compound growth (%) in value of output at constant prices, 1981–2005.

Country	Crops	Livestock	Agriculture
Bangladesh	2.5	3.4	2.6
India	2.5	4.0	2.9
Nepal	3.7	2.4	3.3
Pakistan	2.9	4.9	3.8
Sri Lanka	0.5	1.6	0.7
South Asia	2.5	4.1	3.0
Developing countries	3.0	4.7	3.5
Developed countries	0.4	0.1	0.2
World	**2.5**	**4.1**	**3.0**

Source: FAOSTAT (2005).

Uneven distribution of land is the main cause of rural poverty (Besley and Burgess 1998). Livestock are an important productive asset and a source of income for poor households with little access to land and thus fewer opportunities in crop production. Table 2.3 reveals the distribution of land and livestock assets in India. Landless households have some access to livestock despite having no land. Small landholders comprise 58% of the rural households and share 44% of the arable land. Their share in livestock resources is however much higher, indicating that the distribution of livestock is more equitable compared to land (Sharma and Poleman 1993). The distribution of small animals such as goat, sheep, pig and poultry is even more equitable. In Bangladesh, landless and small farmers (<1.0 ha) own 65% of the cattle, 40% of the buffaloes and 65–75% of goats and sheep (BBS 1996). Since these animals require less initial investment, involve low operational expenses, are prolific breeders and generate quick returns, they are more suited to poor households.

Table 2.3. Distribution of land and livestock assets in rural India, 2002–03.

	Landless (<0.002 ha)	Small (0.002–2 ha)	Medium (2.0–4.0 ha)	Large (>4 ha)
Households (%)	31.9	58.4	6.2	3.5
Share in land (%)	0.0	44.2	21.4	34.4
		Share in livestock (%)		
Cattle	0.6	74.2	14.4	10.8
Buffalo	0.6	70.8	20.5	15.1
Sheep and goat	2.1	77.7	9.4	10.8
Pig	3.8	88.6	11.8	5.3
Poultry	4.3	81.6	6.6	8.4

Source: GOI (2006).

The scale of livestock production is relatively small throughout South Asia. The average number of livestock per household in Nepal is 3.8 cattle/buffalo, 2.2 goats and 4.5 poultry (Joshi and Bahadur 2002). In Bangladesh, herd size varies from 2 cattle for the landless to 4.4 for large farm households, the average being 3.5. For goat and sheep, the average herd size is 7.5 per household (Saadullah 2002). The average size of livestock holdings per household in India is generally small, i.e., 2 bovines and 1 ovine.

Animal husbandry is an important source of employment for the poor, especially women and children. Cropping activities are seasonal and work opportunities in the non-farm sector are not enough to provide round-the-year employment. For instance, animal husbandry in India engages nearly 6% of rural workers; nearly 70% of these are women. In Sri Lanka, women undertake most of the dairy-related activities, besides other household work (Bandara 2002). In Pakistan, women are responsible for 60–80% of the feeding and milking of cattle (Blench et al. 2003). Beyond production, there are income and employment opportunities in marketing, processing and trade in livestock products. In most South Asian countries, milk marketing is dominated by poor informal vendors who sustain their livelihood by selling milk procured from rural producers to urban consumers.

Omore et al. (2004) observed that small-scale dairy marketing and processing offer good opportunities for non-farm rural and urban employment in developing countries.

Better equity in distribution and quick returns in production imply that the poor have more opportunities in livestock production than in crop production. Using state-level data for India from 1983–84 to 1999–2000, Birthal and Taneja (2006) observed greater impact of growth in livestock sector on rural poverty reduction as compared to growth in the crop sector (Figure 2.4).

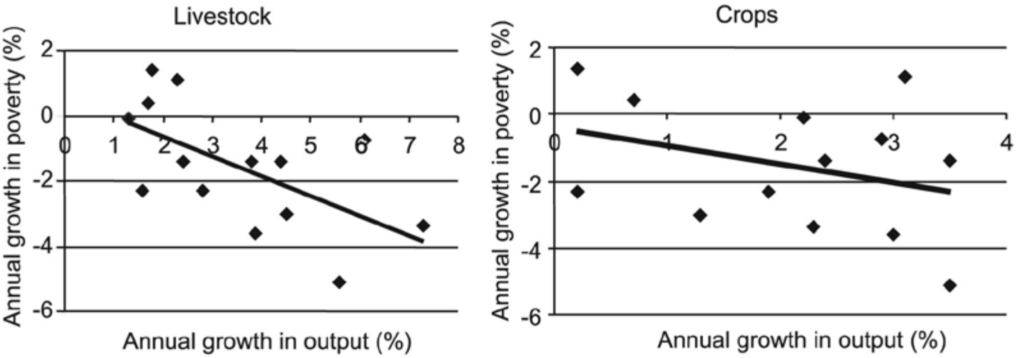

Figure 2.4. Relationship between crop and livestock sector growth and rural poverty in India.

2.3. Challenges to Pro-poor Livestock Growth

The livestock route to poverty reduction is plagued by low levels of livestock productivity due to lack of access to capital, quality inputs, improved technology, support services and product markets for poor livestock producers. The average milk yield of a cow in South Asia is 43% of the world average of 2195 kg/annum (Figure 2.5). So is the productivity of monogastrics. Only buffalo milk and meat yields are comparable to the world average, primarily because South Asia possesses 75% of the world's buffaloes.

Feed is crucial in raising livestock productivity. However, most South Asian countries are still grappling with feed deficits due to high livestock pressure on land. With rising demand for animal foods, the much stronger derived demand for feed has to be met from domestic resources.

At present, crop residues from food-feed cereals such as rice, wheat, coarse cereals, pulses and legumes constitute 45–60% (on dry matter basis) of total feed fed to

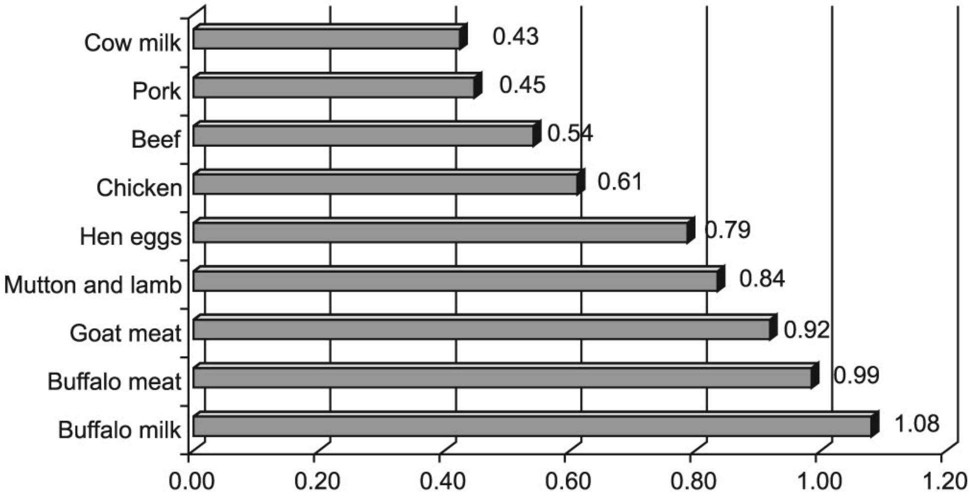

Figure 2.5. Ratio of livestock productivity in South Asia to global average.

large ruminants in South Asia. The rest comes from grazing in rangelands that include pastures, forests, wastelands and fallows (Devendra et al. 2000; Kelley et al. 1993; Kelley and Parthasarathy Rao 1996 and Parthasarathy Rao and Hall 2003). Small ruminants are mainly grazed.

The cultivation of green fodder crops is low and largely restricted to the irrigated tracts and peri-urban areas in Pakistan and India. In the irrigated areas of Pakistan, up to 60% of total feed is derived from fodder crops (Raja 2002). In contrast, smallholder livestock producers depend on grazing and crop residues to meet feed requirements. Since land is scarce, food crops are given priority in rainfed areas, where, in most cases, a second crop cannot be grown due to non-availability of sufficient soil moisture. In Bangladesh, only about 0.1% of the crop area is under fodder crops. In selected areas, 2% of farmers cultivate high-yielding varieties of fodder and the area devoted to fodder cultivation per farm is a mere 0.0008 ha (Alam 1999). In India, less than 5% of the land area is under fodder crops, mostly under irrigated conditions (Kelley and Parthasarathy Rao 1994). In the dry months, stored crop residues are the only feed source until the onset of rains (Devendra et al. 2000 and Kelley et al. 1993). Small ruminants are exclusively grazed, with no or minimal stall feeding. The area under permanent pastures is low, that is 5–6% of the total land area, except in Nepal where it is 12%. At the global level, 27% of land area is under permanent pastures.

Hence, livestock population pressure on grazing lands in South Asia which is 35 times the world average, puts acute pressure on available cropland resources. The area under rangelands is also declining due to cropping, encroachment and deforestation. Overgrazing of rangelands is leading to a deterioration in the yield and quality of grasses (Jodha 1992 and Devendra et al. 2000).

The use of grains and agro-industrial by-products (AIBPs) such as brans and oilcakes is low (Figure 2.6) and mainly restricted to milch animals and commercial poultry. Compound feeds or pre-mixed feeds are restricted to commercial poultry feed, with very small quantities used for ruminants. Less than 5% of grain is used for animal feed in most countries (compared to a world average of 35%), and a lion's share of this goes to poultry. There is low use of grains as feed in South Asia because countries like Bangladesh and Nepal have to first grapple with food-grain security.

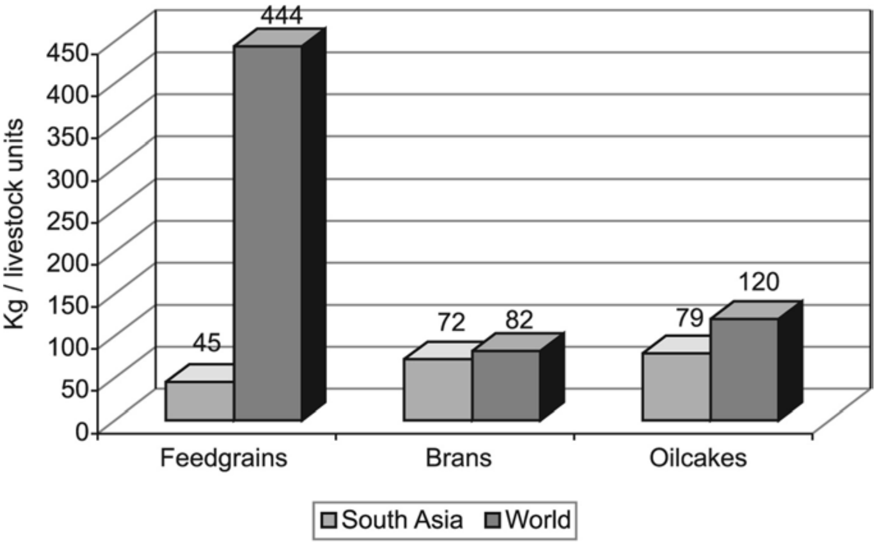

Figure 2.6. Use of agro-industrial feeds, 2003.

Low productivity of livestock in South Asia is also due to non-adoption of technologies or their uptake has not been sustainable. Research in animal production has often highlighted component technologies within the disciplines of nutrition, health and breeding. The lack of multi-disciplinary research has failed to take account of farm-level interactions between genotype, nutrition, management and diseases (Thomas et al. 2002).

Crossbreeding technology, that is the use of temperate cattle to improve milk yields of native breeds, is popular throughout South Asia. However, in many instances, it has been promoted indiscriminately in all ecological regions, where it was found inappropriate to small-scale farming systems and not adaptable to prevailing environmental conditions.

Technological interventions for improving feed-fodder quality abound, but their adoption by farmers is hampered by the failure to demonstrate their cost-effectiveness. These technologies were introduced in farming systems where not required or where there were many constraints to their adoption. Further, despite the availability of several improved fodder species, opportunities to introduce them have not been fully exploited. Most of the improved varieties were suited to irrigated agriculture, thus leaving out large tracts of rainfed agriculture. Even in irrigated agriculture, adoption varied.

Disease diagnosis and monitoring systems are weak, and the emphasis is on curative rather than preventive disease control. The availability of and information on vaccines for diseases is poor (Thomas et al. 2002).

The livestock sector is also vulnerable to poor infrastructure facilities -- storage, processing, marketing and transportation. Lack of appropriate institutions at the grassroots level is another constraint. Since a majority of livestock producers are smallholders, the sale of their small marketable surpluses in distant urban markets lead to very high transaction costs, while local rural markets are sparse. So they face increased competition from large commercial producers, which could undermine their economic viability.

Livestock act as an insurance against income shocks of crop failure. But they are often vulnerable to diseases, droughts and floods, which are quite common throughout South Asia. Institutional mechanisms that provide insurance to animals against such risks are rare. Similarly, poor livestock owners rarely have access to institutional credit.

Globalization of agri-food markets offers an opportunity to enhance exports. However, global trade in livestock products is dominated by a few developed countries, is heavily distorted, and could pose a threat to pro-poor livestock growth. Some countries in the European Union and the United States provide a high level of protection to their livestock industry, making it impossible for developing countries to compete. Developing countries thus face a dual disadvantage -- the imminent threat of cheap imports and the thwarting of their exports due to stringent food safety and quality standards.

Whether smallholders in the region will be able to expropriate demand-led opportunities in livestock production will depend on how public policy is supportive of smallholder livestock production and the extent to which smallholders are able to improve their competitiveness. A number of interactive forces including livestocks' biological potential, agro-climatic conditions, technology, prices, markets and infrastructure influence competitiveness. In other words, there is a need to improve livestock productivity and reduce unit cost of production, which is possible through adoption of appropriate improved technologies. However, since there is considerable heterogeneity across mixed systems within a country, it would be a useful first step to delineate the country into homogeneous subsets to better target technologies and development programs meant to raise overall system productivity. In the next chapter, we take a more comprehensive look at current and future demand for livestock products in South Asia before we proceed to a typological classification of mixed crop-livestock systems.

Chapter 3

Demand and Supply of Livestock Products

As incomes rise, the food basket undergoes significant quantitative and qualitative changes. This is the trend in most developing countries, where per capita as well as total consumption of animal-based foods has been increasing rapidly. This growing demand is being accompanied by an increase in domestic production. Delgado et al. (1999) term this phenomenon as 'livestock revolution'. This chapter provides an overview of the consumption and production trends in animal-based foods in South Asia.

3.1. Demand for Livestock Products

3.1.1. Per Capita Consumption

There has been a substantial increase in consumption of livestock products in South Asia over the last two decades. Between Triennium Ending (TE) 1982 (1980–82) and TE 2002 (2000–02) mean per capita consumption of milk almost doubled from 43 to 79 kg, and that of meat increased from 4 to 5.6 kg (Table 3.1). Increase in meat consumption stemmed primarily from an increase in consumption of non-ruminant meat, especially chicken, while ruminant meat consumption remained static during this period. This is because chicken is widely acceptable, cutting across cultural and religious barriers, and is cheaper compared to mutton and goat meat.

There are considerable inter-country differences in the consumption of livestock products (Table 3.1). Per capita milk consumption is the highest in Pakistan (156 kg), followed by India (79 kg), Nepal (46 kg), Sri Lanka (38 kg) and Bangladesh (16 kg). Pakistan also has the highest per capita consumption of meat (12.1 kg), closely followed by Nepal (10 kg). Average meat consumption in India and Sri Lanka are lower but close to the average for South Asia. Per capita egg consumption varies from 1 kg in Bangladesh and Nepal to 2.4 kg in Sri Lanka. Greater availability of fish is perhaps one of the reasons for the low meat and milk consumption in Sri Lanka and Bangladesh.

Per capita consumption of livestock products has increased in the region. Between 1980–82 and 2000–02, per capita milk consumption increased by 65% in India, 50% in Pakistan and 23% in Bangladesh. It remained almost stagnant in Nepal and Sri Lanka. During this period, meat consumption increased in all the countries, but at varying rates: 106 % in Sri Lanka, 50% in Bangladesh and India, 30% in Nepal and 11% in Pakistan.

Table 3.1. Per capita consumption (kg / capita / annum) of livestock products in South Asia, 1982 and 2002.

	Milk		Meat				Eggs	
			Ruminant		Non-ruminant			
Country	1982	2002	1982	2002	1982	2002	1982	2002
Bangladesh	12.6	15.5	1.0	2.2	1.0	0.8	1.0	1.0
India	47.7	78.7	3.3	3.2	0.0	1.8	1.0	1.5
Nepal	45.8	46.0	9.0	8.8	0.0	1.2	1.0	1.0
Pakistan	104.2	156.1	8.3	9.7	1.0	2.3	1.0	2.1
Sri Lanka	23.5	38.1	2.0	2.0	1.0	4.3	2.0	2.4
South Asia	**42.7**	**79.2**	**4.0**	**3.9**	**0.0**	**1.8**	**1.0**	**1.5**
World	**76.3**	**89.4**	**12.3**	**11.4**	**17.7**	**26.4**	**6.0**	**8.2**

Source: FAOSTAT (2005).

Despite rapid increases in the per capita consumption of livestock products, South Asia remains below the world average. The difference is huge in the case of meat and eggs.

Livestock products are a rich source of protein and nutrients that help overcome problems of nutritional insecurity. Parthasarathy Rao et al. (2005) found a negative relationship between per capita animal protein intake and incidence of undernourishment in countries in the semi-arid tropics. Livestock products make up 8.0% of the calories and 17% of the protein intake (Table 3.2) in South Asia, while at the global level they make up nearly 16% of the calories and one-third of protein intake. Pakistan is the only country where the share of calories and protein from livestock products matches the global averages. In other countries, it ranges from 2.2 to 7.3% for calories and from 6.2 to 15.4% for protein intake.

The relative importance of livestock food products in human nutrition has increased in South Asia. Between 1980–82 and 2000–02, the share of livestock products in calories and protein increased by 29% and 21% respectively. The increase was however confined to India, Pakistan and Sri Lanka, while in Nepal and Bangladesh its share either remained stagnant or declined.

A number of factors influence changes in per capita consumption. These include income growth, urbanization, own price, price of substitutes, tastes and preferences, etc. We will examine the role of income and urbanization in consumption growth. Per capita income in most countries in the region has grown reasonably over the last two decades (Table 3.3). Between 1981 and 2003, it grew at an annual rate of 3.8% in India, 3.3% in Sri Lanka and 3.2% in Bangladesh. The rate of growth was relatively smaller in Nepal (2.4%) and Pakistan (1.6%).

Table 3.2. Share of livestock products (%) in total calories and protein intake in South Asia, 1980 and 2002.

Country	Calories 1980	Calories 2002	Protein 1980	Protein 2002
Bangladesh	2.1	2.2	7.0	6.2
India	5.8	7.3	12.0	15.4
Nepal	8.4	6.4	17.6	13.8
Pakistan	12.3	17.9	25.6	35.4
Sri Lanka	3.3	5.0	9.1	13.3
South Asia	**6.2**	**8.0**	**14.0**	**16.9**
World	**14.2**	**15.7**	**29.0**	**32.3**

Source: FAOSTAT (2005).

Table 3.3. Income growth and urbanization in South Asia, 1981–2003.

Country	Per capita Income – Annual growth (%)	Total population – Annual growth (%)	Urban population – Annual growth (%)	Urban population (%)[1]
Bangladesh	3.2	2.4	4.5	23.9
India	3.8	1.9	2.8	28.1
Nepal	2.4	2.3	6.2	14.7
Pakistan	1.6	2.8	3.6	33.7
Sri Lanka	1.2	1.2	1.1	21.1
South Asia	**-**	**2.1**	**3.1**	**27.9**

1. Percentage of total population.

Urbanization is another important factor influencing growth in consumption of livestock products, since per capita income is higher in urban areas and urban consumers have greater choices. On an average, 28% of the population in South Asia is urban; ranging from 15% in Nepal to 34% in Pakistan. The urban population in the region, however, is growing rapidly. Between 1981 and 2003, Nepal witnessed the highest annual growth (6.2%) in urban population, followed by Bangladesh (4.5%), Pakistan (3.6%), India (2.8%) and Sri Lanka (1.1%).

Besides income growth and urbanization, relative changes in food prices also cause considerable changes in the food basket. Globally, prices of food commodities including dairy and meat products have tended to decline over the last two decades (Parthasarathy Rao et al. 2005). The available information for India shows a decline in the real prices of dairy and poultry products in recent years (Birthal and Taneja 2006). This has made livestock products more affordable, especially to the poor. Kumar and Birthal (2004) have shown that the proportionate increase in consumption of livestock products in India was greater among the poor compared to the rich. This is because the income elasticity of demand is higher at the lower end of income distribution, and the poor spend more on high-value foods with an increase in their income.

3.1.2. Total Consumption

Small increases in per capita consumption could result in significant increases in total consumption due to rapid increase in human population. On the whole, population in South Asia grew at an annual rate of 2.1% during 1981–2003 (Table 3.3). The rate of increase was higher in Pakistan (2.8%), followed by Bangladesh (2.4%), Nepal (2.3%), India (1.9%) and Sri Lanka (1.2%).

Table 3.4. Consumption of milk, meat and eggs (in '000 t) in South Asia, 1982 and 2002.

			Meat			
Country	Year	Milk	Ruminant	Non-ruminant	Total	Eggs
Bangladesh	1982	1,106	149	56	205	53
	2002	2,178	313	113	426	134
India	1982	33,575	2,132	399	2,531	520
	2002	81,293	3,299	1,839	5,138	1,556
Nepal	1982	681	127	11	138	14
	2002	1,108	213	29	242	23
Pakistan	1982	8,740	683	54	737	177
	2002	22,831	1,425	342	1,766	305
Sri Lanka	1982	349	33	21	54	28
	2002	715	37	80	177	45
South Asia	**1982**	**-**	**-**	**-**	**-**	**-**
	2002	**1,08,228**	**5,288**	**2,405**	**2,32,144**	**2,065**

Source: FAOSTAT (2005).

Rapid increases in population have caused dramatic increases in the demand for livestock products in the region (Table 3.4). Between 1982 and 2002 total milk consumption in South Asia increased by 140%, meat consumption by 110% and egg consumption by 160%. At the country level, milk demand in India and Pakistan more than doubled, nearly doubled in Bangladesh and Sri Lanka and increased by 63% in Nepal. Meat demand also witnessed a similar increase in all the countries in the region. Demand for non-ruminant meat grew faster, implying changes in consumer preferences, especially in favor of chicken.

3.2. Supply of Livestock Products

3.2.1. Population

South Asia has huge livestock resources (Table 3.5). It has about 18% of the world's cattle, 74% of buffaloes, 28% of goats, 8% of sheep, 5% of poultry and 2% of pigs. India accounts for the bulk of livestock population in the region, sharing over 76% of cattle and buffaloes, 70% of sheep, 55% of goats, 93% of pigs and 56% of poultry. Pakistan too has a sizeable population of buffaloes, small ruminants and poultry. Bangladesh's share in cattle and poultry population is as high as that of Pakistan. Its share in goats is 17%.

Table 3.5. Distribution of livestock population (in million nos.) and growth rates in South Asia, 2003–05.

Country	Cattle	Buffaloes	Sheep	Goats	Pigs	Poultry
Bangladesh	24.5	0.9	1.3	36.9	0.0	142.0
India	186	97.4	62.3	120.0	14.1	421.3
Pakistan	23.8	25.5	24.7	54.7	0.0	160.3
Sri Lanka	1.2	0.3	0.00	0.4	0.1	10.8
South Asia	**242.4**	**128.1**	**89.1**	**219.0**	**15.1**	**757.2**
World	**1,364.4**	**172.0**	**1,061.2**	**795.3**	**949.9**	**16,483.3**
	% Annual growth rates (1980–2005)					
Bangladesh	0.5	2.5	3.3	6.2	-	3.8
India	-0.1	1.6	1.4	1.2	1.9	3.1
Nepal	0.3	1.9	0.5	1.7	4.1	6.0
Pakistan	1.8	3.3	0.3	3.3	-	5.9
Sri Lanka	-2.0	-5.5	-5.2	-0.8	-0.5	2.4
South Asia	**0.1**	**1.8**	**1.1**	**2.2**	**1.9**	**3.8**

Source: FAOSTAT (2005).

Growth in population of most species in South Asia has been stronger compared to global trends (Table 3.5). During 1980–2005, poultry was the fastest growing segment, driven by increasing demand for poultry products and supported by genetic improvements on the supply side. Goat numbers also increased at a faster rate (2.2%), reflecting a preference for small ruminants, particularly by the poor. Growth was fastest in Bangladesh, mainly because of the preponderance of extremely small sized land holdings unable to support large animals. With the very high incidence of rural poverty in Bangladesh compounded by the lack of access to land for feed and fodder, the poor prefer small animals that yield quick returns with less initial investment and involving minimal operational costs.

Among large ruminants, the buffalo population has increased in much of South Asia. Cattle population too has increased, except in India where it has remained stagnant. Sri Lanka witnessed a decline in the population of most species except poultry. These trends suggest a shift in the structure of livestock production in the region in favor of poultry, goats and buffaloes.

3.2.2. Production Performance

In 2003–05, South Asia produced 123 million tons of milk accounting for one-fifth of the global milk output (Table 3.6). India with a share of 74% in South Asia, is the largest producer of milk in the world. Pakistan accounts for 23%. Buffalo is the major milch species in the region, contributing 57% to total production. Cattle accounts for 39%, and the rest comes from goats and sheep. At the country level, nearly two-thirds of the milk output in Pakistan and Nepal and 56% in India come from buffaloes. The bulk of milk in Bangladesh comes from goats, and in Sri Lanka from cattle.

Table 3.6. Milk production and growth rate in South Asia.

	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia	World
Commodity	Production of milk ('000 t), 2003–05						
Milk							
Cow	799	37,500	370	8,847	136	47,694	5,24,130
Buffalo	23	50,527	864	19,186	26	70,626	76,392
Goat	1,416	2,720	65	657	5	4,862	12,483
Total milk	**2,263**	**90,747**	**1,312**	**28,721**	**168**	**1,23,252**	**6,21,449**
	% Annual growth rates (1980–2005)						
Milk							
Cow	0.3	4.4	2.9	6.8	-1.1	4.6	0.7
Buffalo	6.0	4.3	2.3	5.0	-4.0	4.4	4.3
Goat	6.2	4.6	1.4	2.2	-0.3	4.5	2.2
Total milk	**3.1**	**4.3**	**2.4**	**5.4**	**-1.7**	**4.5**	**1.0**

Source: FAOSTAT (2005).

Despite South Asia's sizeable share of world livestock population, its share in meat output is low (3.7%). This is because large ruminants here are raised mainly for milk, and meat is an adjunct. Large ruminants account for nearly half of the total meat output (Table 3.7). The share of monogastrics is 33% and that of small ruminants 16%. At the global level, monogastrics (pig and poultry) are the main suppliers of meat.

There are significant inter-country differences in the composition of meat output. Buffalo accounts for more than half of the total meat output in Nepal. In Pakistan and India, meat production is quite diversified. In contrast, over 70% of the meat production in Sri Lanka comes from poultry.

Table 3.7. Meat production and growth rate in South Asia.

	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia	World
Commodity	Production ('000 t), 2003–05						
Meat							
Beef and veal	180	1,483	48	454	29	2,199	59,601
Buffalo	4	1,479	134	521	4	2,142	3,093
Mutton and lamb	3	238	3	163	0	407	8,178
Goat	137	474	41	357	1	1,011	4,384
Pig	0	495	16	0	2	514	1,00,493
Poultry	116	1,781	16	401	94	2,408	78,935
Total	**449**	**6,090**	**257**	**1,912**	**130**	**8,846**	**2,59,715**
Eggs (hen)	135	2,442	26	383	51	3,037	58,017
Meat	% Annual growth rates (1980–2005)						
Beef and veal	1.8	2.4	0.9	3.9	0.6	2.5	1.0
Buffalo	3.2	2.4	3.1	4.2	-1.5	2.8	2.7
Mutton and lamb	6.0	1.7	0.5	0.9	-3.1	1.3	1.4
Goat	7.4	1.7	2.4	3.1	-2.8	2.7	4.0
Pig	-	2.5	4.4	-	1.5	2.5	2.8
Poultry	3.7	11.9	5.2	8.9	8.2	10.0	5.0
Total	**3.4**	**3.5**	**2.6**	**4.1**	**4.3**	**3.6**	**2.8**
Eggs (hen)	6.8	5.9	2.9	5.2	2.2	5.7	3.5

Source: FAOSTAT (2005)

Livestock outputs, milk, meat and eggs grew at an annual rate of 4.5%, 5.6% and 5.7% respectively in South Asia between 1980 and 2005 (Tables 3.6 and 3.7). These trends are quite robust and prevail throughout the region with a few exceptions -- negative growth in milk production in Sri Lanka and sluggish growth for all products in Nepal.

Amongst all livestock commodities, poultry meat production grew fastest throughout the region except in Bangladesh. The annual rate of growth was 12% in India, 9% in Pakistan, 8% in Sri Lanka and 5% in Nepal. Buffalo meat production grew between 2.4 and 4.2% a year except in Sri Lanka, where growth was negative. Beef production too experienced similar trends in these countries.

3.3. Productivity of Livestock Products

Productivity of livestock products has been low throughout South Asia. The average annual milk yield of a cow ranges between 206 kg in Bangladesh to 1202 kg in Pakistan (Table 3.8). A similar pattern prevails in the case of buffalo milk. On the whole, milk yields of both cows and buffaloes in South Asia increased during 1980–2005, but mainly in India and Pakistan. In other countries, it remained almost stagnant. Further, both in India and Pakistan, cow milk yield increased faster, and accounted for 60% and 28% of output growth respectively. The share of yield in growth in buffalo milk production was 40% in India and 21% in Pakistan.

Table 3.8. Milk productivity and growth rate in South Asia.

	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia	World
Commodity	Kg/animal/annum (2003–05)						
Cow	206.4	970.7	417.0	1,202.2	624.7	932.8	2,194.8
Buffalo	407.1	1,457.6	848.6	1,959.9	488.1	1,549.5	1,433.2
Goat	80.0	114.4	50.0	87.6	30.0	96.0	83.0
	% Annual growth rates (1980–2005)						
Cow	0.0	2.6	1.2	1.9	-0.1	2.7	0.4
Buffalo	0.2	1.7	0.2	1.1	-0.7	1.6	1.7
Goat	0.0	0.8	0.0	-0.5	0.0	0.4	-0.1

Source: FAOSTAT (2005)

Productivity of meat animals has been stagnating and been at a low level, but with some inter-country variations (Table 3.9). Average beef yield is 109 kg in South Asia, ranging from as low as 70 kg in Bangladesh to 190 kg in Pakistan. Buffalo meat yield is the highest in Nepal and the lowest in Bangladesh. Sri Lanka's meat yield from small animals including sheep, goat, pigs and poultry, is the highest in the region. Further, over the last 25 years, yield of most meat animals in the region has hardly shown any improvement except in Pakistan.

Inter-country differences in livestock productivity could be due to an amalgam of factors related to animal genetics, feeding, health, system of rearing and infrastructure. Higher milk yields in India and Pakistan and pork yield in Sri Lanka are due to improved breeds and stall feeding. Similarly, intensive rearing practices account for the relatively greater meat production per sheep and goat in Sri Lanka.

This analysis of production performance suggests that the growth is largely number-driven, and cannot be sustained for long. Future growth will have to come from improvements in feeding and animal health, and a technological breakthrough in animal genetics.

Table 3.9. Meat Productivity and growth rate in South Asia.

	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia	World
Commodity	Yield (kg/animal/annum), 2003–05						
Beef and veal	70.0	103.0	85.0	190.4	137.2	108.9	201.2
Buffalo	76.6	138.0	216.9	120.6	113.0	136.1	138.1
Mutton and lamb	7.0	12.0	9.0	16.5	20.0	13.4	15.6
Goat	7.0	10.0	11.5	17.0	20.2	11.0	12.3
Pig	0.0	35.0	31.8	0.0	81.6	35.0	78.2
Poultry	0.7	1.0	0.8	1.1	1.4	1.0	1.6
Duck	1.0	1.3	0.2	1.3	1.3	1.2	1.4
Eggs (hen)	1.8	11.6	3.9	5.6	8.6	8.3	10.5
	% Annual growth rates (1980–2005)						
Beef and veal	1.07	0.75	0.00	1.93	0.06	1.03	0.13
Buffalo	0.14	0.00	0.89	1.26	0.00	0.28	-0.02
Mutton and lamb	0.94	0.00	-0.57	1.43	0.00	0.48	0.33
Goat	0.71	0.00	1.11	1.95	0.04	0.43	0.46
Pig	-	0.00	0.29	-	0.29	0.00	0.43
Poultry	-0.35	0.90	0.15	1.47	0.83	0.46	0.68
Duck	-	-	-	-	-	-	-
Eggs (hen)	0.34	1.35	-0.08	1.24	-0.46	0.98	0.64

Source: FAOSTAT (2005)

3.4. Projected Demand for Livestock Products to 2020

Factors underlying demand growth in South Asia, such as income growth and urbanization, have been quite robust in the recent past, and are likely to continue to be so in the near future. This implies that rising demand for livestock products is unlikely to slow down.

Table 3.10 presents demand estimates[2] for livestock products to the year 2020. In South Asia, total consumption of milk is expected to rise to 211 million t in 2020, almost double that in 2000–02. At the country level, it is likely to grow more rapidly in India and Pakistan, requiring 156 million t and 49 million t respectively to meet human consumption needs.

Table 3.10. Demand projections[1] (in million t) to 2020 for livestock products in South Asia.

Livestock product	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Milk	3.27	156.00	1.68	48.86	1.27	211.1
Bovine meat	0.22	3.72	0.27	2.08	0.03	6.3
Mutton and goat meat	0.55	1.04	0.06	0.97	0.002	2.6
Pork	0.00	1.03	0.03	0.00	0.002	1.1
Poultry meat	0.23	3.53	0.03	1.35	0.26	5.4
Total meat	1.03	9.56	0.39	4.44	0.30	15.7
Eggs	0.38	3.67	0.04	0.72	0.06	4.9

1. The demand projections are based on income elasticity of demand for livestock products, income growth and population growth.
Sources: FAOSTAT, (2002) and World Bank (2000).

Per capita consumption of milk is estimated to increase from 38 to 57 kg in Sri Lanka, 78 to 120 kg in India and from 156 to 214 kg in Pakistan. Per capita increases in milk consumption in Bangladesh and Nepal are expected to be very minimal (Table 3.11).

Table 3.11. Projected per capita consumption[1] (kg / capita / annum) to 2020 for livestock products in South Asia.

Livestock product	Bangladesh	India	Nepal	Pakistan	Sri Lanka	South Asia
Milk	16.5	120.6	47.4	214.5	57.4	456.4
Bovine meat	1.1	2.9	7.5	9.1	1.5	22.1
Mutton and goat meat	2.8	0.8	1.7	4.3	0.1	9.7
Pork	0.0	0.8	1.0	0.0	0.1	1.9
Poultry meat	1.2	2.7	0.9	5.9	11.9	22.6
Total meat	5.2	7.4	11.1	19.5	13.7	56.9
Eggs	1.9	2.8	1.0	3.2	2.9	11.8

1. Projected demand from Table 3.10 divided by projected population.
Sources: FAOSTAT (2002) and World Bank (2000).

2 The projections are based on past income growth, income elasticity of demand and future growth in human population using the formula $D_t = D_o (1+d)^t$, where D_t is the total consumption of livestock products at a future time t; D_o is the total consumption in the base year; and $d = p+i^*\eta$, that is the sum of future growth in human population n (p) and the income elasticity (η) weighted per capita income growth (i) in the recent past.

Increase in meat demand is likely to be substantial in 2020. Rapid increases in total as well as per capita consumption are expected in Sri Lanka, Pakistan and Bangladesh. Per capita meat consumption would increase from 6.2 to 13.7 kg in Sri Lanka, 12.1 to 19.5 kg in Pakistan and from 3 to 5.2 kg in Bangladesh.

Trends in meat demand are expected to undergo significant changes by 2020. Demand for poultry meat will increase faster throughout the region, while the trend in bovine meat consumption is likely to remain sluggish, except in Pakistan. Demand for small ruminant meat will grow in Bangladesh.

The question, however, remains whether South Asian countries will be able to meet the rising demand for livestock products from domestic production? The growth rates in production needed to meet the demand in 2020 are shown in Table 3.12. The production performance of most commodities between 1981 and 2005 was quite robust. In the case of milk, a continuation of past trends in all countries except Sri Lanka would be sufficient to meet demand growth from domestic production.

Table 3.12. Growth in production of livestock products required to meet demand in 2020 in South Asia (% per annum)[1].

Livestock product	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Milk	2.3	3.4	1.6	3.4	13.5
Bovine meat	1.1	1.4	2.5	4.9	0.6
Mutton	8.9	2.4	2.0	4.0	4.4
Pork	NA	4.7	4.0	NA	0.07
Poultry	4.4	4.4	4.0	7.9	6.6
Total meat	5.3	2.9	2.6	5.4	5.4
Eggs	6.7	2.6	2.7	4.0	1.0

1. Based on projected demand.

The required growth rates in meat production in Bangladesh, Pakistan and Sri Lanka are greater than what have been achieved in the past, indicating that these countries need to step up domestic production. India and Nepal would adequately satisfy the demand growth if current production trends stretch until 2020. The demand for poultry meat is likely to continue to grow faster. So India and Sri Lanka would have to accelerate growth in poultry production.

On the whole, South Asian countries would be able to meet the demand growth through domestic production assuming that past production trends persist. Sustaining these trends would however be difficult, as the number-driven growth in the past will come under stress due to declining land holding size and deteriorating grazing resources. So future growth will have to stem from enhanced productivity.

Chapter 4

Crop-Livestock Systems in South Asia: Methodological Approach

An important characteristic of the livestock sector in South Asia is its close integration with the crop sector through a two-way flow of inputs and outputs. For centuries, livestock (mainly bullocks) have provided draft power and manure for cropping activities. On the other hand, agriculture provides crop residues and by-products as feed for livestock. Such a symbiotic relationship between crop and livestock systems is common throughout South Asia and has sustained both the systems providing better livelihood to the farmers. Evidence from India indicates that integration of livestock activities into cropping systems raises farmers' income 1.5- 3.0 times (Ramarao et al. 2005) The degree of integration however varies with country and depends on its livestock composition, agro-ecological conditions, socio-economic environment and market development.

This chapter describes the evolution of livestock production systems, and goes on to provide a methodological framework for the construction of a typology of mixed Crop-Livestock Systems (CLSs), which is useful for targeting technology and development interventions.

4.1. Evolution of Livestock Production Systems

Based on the degree of integration of livestock with crops, Sere and Steinfeld (1996) have categorized global livestock production into three broad systems, namely grassland-based system, mixed farming system and landless (industrial) livestock production system. These are further sub-divided into 11 systems based on agro-ecological conditions, rainfall, irrigation, land types, etc. (Table 4.1).

These systems have evolved over time in response to a number of interactive forces such as population growth, technological change, developments in markets and infrastructure and policy environment. At low population density, crop and animal production tends to be extensive because of abundant land availability. The interaction between crop and livestock production is weak, and the link is through contracts among specialized producers of crops and livestock involving manure, animal traction and livestock products.

Table 4.1. A classification of the world's livestock production systems.

Major system	Sub-system
Grassland-based system	Temperate and tropical highland Humid/sub-humid tropics and sub-tropics Arid/semi-arid tropics and sub-tropics
Mixed farming system	Rainfed mixed farming system -Temperate and tropical highland -Humid/sub-humid tropics and sub-tropics -Arid/semi-arid tropics and sub-tropics
	Irrigated mixed farming systems -Temperate and tropical highland -Humid/sub-humid tropics and sub-tropics -Arid/semi-arid tropics and sub-tropics
Landless livestock production system	Landless monogastric system Landless ruminant system

Source: Sere and Steinfield (1996).

However, as population increases, there is increasing pressure on cropland, and fallows and pasturelands are increasingly brought under cultivation. This in turn raises farmers' demand for manure and animal traction. Herders, on the other hand, tend to acquire land to grow crops and crop residues for their herds. There is thus a move towards crop-livestock interaction, where crops and animals are integrated on the same farms (McIntire et al. 1992)[3].

The growing demand for crop and livestock products further intensifies production of both crops and livestock. Availability of modern inputs (fertilizers and ready-mix feeds), development of infrastructure, transport systems and new technologies (such as fodder production) lead to the re-emergence of specialized production systems, known as industrial systems. In most developing countries, specialized livestock and crop/fodder production takes place primarily in peri-urban areas to cater to the urban demand for livestock products. Additionally, in the quest to achieve self-sufficiency in food production, many governments subsidize tradable inputs (fertilizers, concentrate feeds, diesel, etc.) to the extent that the terms of trade become unfavorable to the use of non-tradable inputs

[3] McIntire et al. (1992) carry the debate further to show that 'as population density increases, crop-livestock interactions follow an inverted-U shape, integration being weak in the beginning, then increasing and finally decreasing.

(manure and crop residues). That weakens crop-livestock integration, favoring specialization (McIntire et al. 1992).

Globally, Mixed Crop-Livestock Systems are the most important system, producing 90% of global milk and 54% of beef. The industrial systems contribute 37% of global meat production, two-thirds of which comes from non-ruminants, i.e., pig and poultry (de Haan et al. 1997). The grazing systems are the least important, contributing only 9% of global meat production.

Over the last two decades, industrial production systems have grown at twice the rate of mixed systems, and more than six times the grazing systems (FAO 1996). The higher growth in industrial systems is mainly driven by pig and poultry production. Despite the rapid growth of industrial systems, mixed Crop-Livestock Systems dominated by ruminants are widespread in developing countries. These systems serve the purpose of risk-coping, with livestock providing an important avenue for farm diversification and consumption smoothening (Williams et al. 2000). Evidence suggests that integration of livestock with crops improves farm productivity and household income (Ogle 1996).

Mixed Crop-Livestock Systems are partially closed and thus are environmentally the most benign. Waste products of one enterprise are used by another enterprise and thus minimize negative externalities to the environment (Thomas and Zerbini 1999). On the other hand, industrial systems depend on the external supply of feed and other inputs, and are environmentally least desirable. These systems need to internalize environmental costs. Moreover, since commercial livestock production is based on very few breeds, it poses a threat to domestic animal diversity (de Haan et al. 1997).

4.2. Mixed Crop-Livestock Systems (MCLS)

The interaction between crop-livestock production is unique to most developing countries, including those in Asia. Mixed systems are important in Asia and account for almost its entire milk production, 90% of bovine meat and 75% of small ruminant meat (Sere and Steinfield 1996). In South Asia, mixed crop-livestock farming is the dominant form of production system. However, extensive grazing systems are important in the arid rangelands of India and Pakistan. In the mountainous Himalayan region of Nepal, pastures are important feed resources.

A major feature of MCLS in South Asia is their huge diversity and complexity in terms of crops grown and livestock species raised. Annual and perennial crops, tree species, ruminants and non-ruminants are integrated on the same farm to reduce production risks, improve food security, enhance income and utilize family labor. In such systems, livestock are a living savings account with offsprings serving as interest. They act as a cushion against risk and uncertainty in crop production.

Mixed farming systems in South Asia are dynamic and evolving due to changes in the external environment (demand, prices, policies, etc). Over the last four decades, South Asian countries have come out of the shadow of food insecurity through intensive use of high-yielding seeds, fertilizers and mechanical power. The importance of the non-food functions of livestock (draft and manure) is diminishing (Birthal and Parthasarathy Rao 2002). Livestock are now being viewed more as a source of food and an instrument of poverty alleviation (Delgado et al. 1999). Agro-economic, technological, infrastructure and socio-economic factors (including policy) such as a decline in the use of draft power in most countries in the region, preference for buffalo milk, and faster growth in the population of small animals are driving this transformation in MCLS.

Livestock in MCLS are primarily large and small ruminants that can convert highly fibrous material and grasses with a little or no alternative use into valuable products (FAO 2000). Livestock will continue to play an important role in smallholder-dominated agrarian economies of South Asia. The challenge, however, lies in improving the productivity of MCLS in a manner compatible with the environmental and social ethos.

4.3. Capturing System Diversity – A Typological Approach

There is considerable variation in agro-ecological and socio-economic situations within any given country, which in turn influences a farmer's choice of crops and animal species. Planning agricultural development is thus complicated by variations in agro-ecological and socio-economic conditions underlying agricultural practices. In such a situation, it becomes essential to divide the country into regions/systems, each of which can be considered as a unit while introducing technology or designing agricultural development strategies.

By focusing attention on a limited number of regions/systems that offer similar opportunities for response to development initiatives, a set of well-defined regions is a useful aid in targeting technology, developing research programs, policy initiatives and infrastructure development projects. Delineation of homogeneous regions also provides a clear focus in measuring achievement and impact, which in turn facilitates resource allocation decisions across alternative uses. In research, the identification of similar geographical units to which successful development initiatives can be extended helps maximize economies of scale (Bidinger et al. 1994). Analysis of the spatial units thus created provide information about the predominant causes of differences in agricultural systems, as well as the rate of adoption of development initiatives across rural areas.

4.3.1. Previous Approaches

In view of the complexity and diversity of agricultural activities pursued within a given country, several approaches were used to delineate homogeneous regions that would be amenable to policy prescriptions and technology targeting. Since the primary goal of agriculture is increasing agricultural production, agro-ecological characteristics --physiography, climate and soils -- were assigned primary importance in the classification of agricultural systems (Sehgal et al. 1992; ARPU 1993; GOI 1989 and Scholz 1987). For example, India and Sri Lanka are divided into agro-ecological zones based on physiographic factors while Nepal is divided into climatic and development regions. However, given the broad vision of agricultural development, i.e., increasing returns to farmers, delineation of regions based only on agro-ecological characteristics is too narrow to be considered homogeneous for agricultural development planning. It does not incorporate socio-economic factors that determine the nature of constraints limiting the ability of farmers to produce more efficiently and sustainably.

It is thus important to construct a typology that identifies regions having similar constraints to agricultural development, in which development initiatives can be directed to identifiable economic activities, and are homogeneous in terms of the expected outcomes in response to an external change.

4.3.2. Constructing an Improved Typology of Agriculture

An improved typology should integrate key agro-ecological and socio-economic factors influencing agricultural production. There are two approaches to doing this: structural approach and agricultural activity-based approach. The structural approach focuses on the determinants underlying agricultural production. The activity-based approach, on the other hand, focuses on the results of the interactions of the underlying variables themselves, and follows what is analogous to a reduced form approach in regression analysis.

The structural approach identifies regions by classifying them into micro units e.g., districts into groups that have similar patterns of the underlying structural variables (agro-ecological and socio-economic characteristics). The regions/systems in the typology are structurally similar by definition, and hence the responses to external changes would be similar, provided one has identified all the relevant structural variables. Moreover, one would expect similar agricultural systems to emerge from similar structural characteristics. Thus, the resulting regions would also be identifiable in terms of types of agricultural systems or production systems.

However, the success of this approach hinges on the list of variables being comprehensive. A comprehensive identification of variables is usually not possible. Nor is it possible to perfectly model the interactions among underlying variables. This gives rise to difficulties in determining the appropriate weight for a variable or the relevant threshold levels for the variables.

Alternatively, features of existing agricultural activities that are in themselves manifestations of the various factors that influence or determine farmers' decisions can be observed. The activity-based approach thus does not require an exact model of the interactions between the underlying structural features. One or more integrator variable(s) would reduce the onus on the researcher for a comprehensive identification of determining factors and their appropriate weights. The final typology should be such that each region can be identified on the basis of similar specific agricultural activities and their relative importance, rather than being simply a nondescript agglomeration of areas formed on the basis of a combination of weighted "key" variables.

One possible integrator variable is the set of agricultural activities (crop and livestock) undertaken by farmers. This is because agricultural activities undertaken by farmers are an articulation of the multiple objectives of the farm within the underlying agro-ecological and socio-economic constraints of the environment (Collinson 1996). Agricultural activities are likely to fulfill the required role of an integrator of key structural variables. Regions identified on the basis of agricultural activities can then be expected to exhibit similar patterns in both the underlying socio-economic and biophysical characteristics that have been identified (and perhaps some that were not identified). Agricultural activities (crop and livestock) dominate almost all rural economies. Development strategies, research programs, infrastructure investments and policy instruments must be related to specific features of agricultural activities to induce economic development in rural areas.

Kelley et al. (1997) and ICRISAT (1999) used the activity-based approach to construct a rainfed agricultural typology for India. The approach was validated using discriminant functions. The agro-ecological variables could correctly classify 19–36% of the districts with agricultural activity as the grouping variable. The discriminating power of the socio-economic predictor variables was much higher than that of the agro-ecological variables alone. Agro-ecological and socio-economic variables (normal rainfall, soil, soil type, length of growing period, population density, wage rate, road and market density, input use, credit availability, etc.) together could correctly classify 87–90% of the districts into homogeneous systems. Thus, the activity-based approach effectively integrates socio-economic factors with agro-ecological ones in grouping homogeneous units.

4.4. Data and Methodology

We used the activity-based approach to delineate mixed farming systems in South Asian countries into homogeneous units in respect of crops grown and livestock species raised. Its application in different countries was however guided by the availability of required data. A brief description of the data and the methodology adopted in different countries follows.

4.4.1. India

To create and characterize the typology of Mixed Crop-Livestock Systems, we used data on key agricultural, socio-economic and agro-ecological variables for 472 districts spread over 16 major states of India for the period between 1970 and 1998 (for details of variables in the dataset and conversion of livestock output in value terms, see Appendixes 4.1 and 4.2). The agricultural activities included production of crops and livestock, paddy, wheat, sugarcane, soybean, sorghum, maize, pearl millet, small millets, chickpea, pigeonpea, other pulses, rape and mustard, groundnut, cotton, fruits, vegetables, cattle, buffalo, sheep, goat and poultry. Local crops with a very small share in cropped area were not included in the analysis. In a majority of the districts, the crops included accounted for 85–90% of the total cropped area. The outputs, main as well as secondary (crop residues), of these activities were standardized into constant monetary values by multiplying them by farm harvest prices.

The database used for this study is the apportioned data set, i.e., boundaries of the districts formed after 1970 have been adjusted to the 1970 district boundaries. A total of 160 new districts were formed since 1970, and the data relating to them were returned to their parent districts. The apportioned data set includes 308 districts that provide continuity in data, thus making it possible to study changes in Crop-Livestock Systems over time.

Cluster analysis techniques were used to create crop-livestock typologies. These techniques explore data sets to assess whether or not they can be summarized meaningfully in terms of a relatively small number of groups that resemble one another, and are different in some respects from objects in other groups (Everitt et al. 2001).

If the grouping is to be done using a small number of variables, say 2 or 3, clustering can be done by eyeballing data. When there are a large number of integrating variables, cluster analysis is a very useful tool of grouping and characterizing observations given little previous knowledge of data and without explicit specification of the model. Thus, in contrast to more explicit techniques such as regression analysis, errors due to model mis-specification can be avoided. In choosing a clustering method, decisions need to be taken in respect of (i) measurement of similarity between variables; (ii) appropriateness of the clustering algorithm; and (iii) number of homogeneous units.

In this study, we need to group districts with similar crop and livestock activities to delineate homogeneous Crop-Livestock Systems. The value shares of different agricultural activities in the gross value of agricultural production in 1996–98 were used in clustering these into homogeneous crop-livestock groups. Before using the clustering technique, the data were standardized to unit variance or each variable was divided by its sample range.

4.4.2. Nepal and Sri Lanka

District-level data were compiled for Nepal and Sri Lanka on crop and livestock activities for 1980–81, 1990–91 and 1998–99. The data sets included information on cropping patterns, livestock population, agro-climatic conditions and infrastructure but were not as comprehensive as that for India. For example, data on value of livestock products were not readily available and land use statistics were not updated regularly. Data on area under irrigation and mechanization are hard to get at the district level. For Sri Lanka, there is no data on feed availability from crop residues, grazing lands, etc. In view of these limitations, the activity-based approach was modified while constructing the typology in these countries. Clustering districts into Crop-Livestock Systems was done in two stages. In the first stage, districts were clustered into systems based on crop activity, i.e., share of major crops in total cropped area. In the second stage, livestock densities of different species were superimposed on the crop zones delineated in the first stage, and the districts were regrouped based on the relative importance of crop and livestock activities.

Appendix 4.1. List of variables: District-level Database.

A. Crop, livestock and land use

Cereals: Area, production and productivity
Pulses: Area, production and productivity
Oilseeds: Area, production and productivity
Selected cash crops: Area, production and productivity
Crop-wise irrigated area
Cropped and irrigated area (single, double cropped, etc.)
Livestock numbers (detailed breakups by species and type)
Agricultural implements (tractors, power tillers, pumps, threshers, plows, etc.)
Value of livestock outputs (milk, meat and eggs, for few points in time)
Farm harvest prices (for all crops)
Land use (geographical area, forest area, grazing land, fallow land, arable land, etc.).

B. Socio-economic

Fertilizer consumption and field labor wages
Population census data (population, literacy, cultivators and agricultural laborers)
Number of operational holdings and area by size of land holding
Distribution of livestock by species and size of land holding (only state-level data)
Per capita consumption of milk, meat and eggs (only state-level data)
Road length and market density
Veterinary care and animal infrastructure institutions.

C. Agro-ecological

Annual rainfall and monthly rainfall (June, July + August)
Annual monthly normal rainfall*
Annual monthly normal potential evapo-transpiration*
Length of Growing Period *
Soil type*
Moisture Availability Index*

* Single point data, varying across districts only.

Appendix 4.2. Value of livestock and crop production.

Livestock value data were available only at the state level for three points in time: 1982, 1991 and 1998 at current prices. The state-level data on livestock outputs were apportioned to the districts in each state based on livestock population numbers in each district. Since livestock population consists of both indigenous and improved breeds, population data were standardized based on yield differences between improved and indigenous breeds as follows:

Total standardized cattle in milk population = Indigenous cattle (in milk) + [crossbred cattle (in milk) × (yield of crossbred in milk/yield of indigenous in milk)].

Egg (chicken population used for egg):
Standardized chicken population = Desi [indigenous layer (population)] + [improved layer (population) × (egg yield of improved layer/egg yield of desi layer)].

Meat (chicken population used for meat):
Standardized chicken population = Desi + (improved × 1.1).
Meat (pig population):
Standardized pig population = Indigenous + (crossbred × 1.5).

To change the base of livestock value to constant prices, i.e., 1980–82 base prices; 1991 and 1998 current value × Agriculture Gross Domestic Product deflator (i.e., 0.38 and 0.2071 respectively).

Dung value: buffalo and cattle

Cow dung per day:
Number of cattle in milk × 7.74 + cattle dry × 5.97 + adult male cattle × 7.86 + young stock × 4.93.

Buffalo dung per day:
Number of buffalo in milk × 9.69 + buffalo dry × 8.29 + adult male buffalo × 5.73 + young stock male × 2.80 + young stock female × 3.9.
The share of cattle and buffalo can be derived from the total dung produced per day.

Draft power value: cattle, buffalo and camel

Data on value of draft power is not available. This was generated at the district level in the following manner.

The total value of bullock labor for major crops was calculated state-wise by taking the value of draft power for crop i × area under crop i. This was summed up for all the main crops and divided by the total area under the crops to get the per hectare value of animal draft power. Multiplying by the state Gross Cropped Area to derive the value of total draft power upscaled this. The total value was then distributed across districts between the species, i.e., cattle, buffalo and camel, based on their horsepower as follows:

Cattle HP = 0.5, buffalo HP = 0.5 and camel HP = 1.08.

Crop value

Crop production × farm harvest prices (1980–1982 base prices) + fodder value (rice, wheat, sorghum, pearl millet, barley, maize, finger millet, chickpea, pigeonpea, groundnut, sugarcane and cotton). Fodder value is based on fodder yields relative to grain × fodder prices.

The crop value is then boosted by dividing it by the proportion of total cropped area covered by the crops included in the analysis, i.e., total area of all crops included/total cropped area. This is done to account for crops not included in the analysis.

Value of fruits and vegetables

Production data for fruits and vegetables is not available at the district level. The value of fruit production at the state level is calculated by using state-level production data and average farm harvest prices, This is then converted into value per hectare, which is then used to arrive at district-wise values based on the area under major fruits and vegetables. Using appropriate deflators, the data are reported in 1980–82 constant prices.

Chapter 5

Typology of Mixed Crop-Livestock Systems in India

India has a diverse and dynamic agricultural sector. Mixed faming systems are the dominant form of agricultural production. However, these systems exhibit wide variations in terms of composition, productivity and growth depending on agro-climatic and socio-economic conditions. Past attempts to divide the country into agro-climatic zones failed to integrate socio-economic activities. This chapter attempts to develop a typology of mixed farming systems that incorporates both agro-climatic and socio-economic characteristics underlying the system.

5.1. Crop-Livestock Systems Typology

Using the clustering approach described in the previous chapter, we obtained a 15-system typology of Mixed Crop-Livestock Systems for India after making some minor adjustments in the systems emerging from the analysis (Table 5.1 and Map 5.1). Two systems (i.e., 3 and 5) were subdivided into 2 and 3 systems respectively because clusters emerged in geographically distant areas. Finally, 18 CLSs were identified. The states and districts under which each CLS falls are given in Appendix 5.1.

Cropping activities dominate most of the systems, but livestock activities are amongst the top four agricultural activities. Paddy is the dominant activity in six, wheat in three, coarse cereals in two, oilseeds (groundnut and soybean) in three and sugarcane in two systems. Buffalo and cattle are the most important agricultural activities in one system each, and are the second most important activities in four systems. Clustering units, i.e., districts are contiguous in most systems, making targeting of development interventions in a particular system easier and cost effective.

For the sake of convenience in reporting, agro-ecological conditions were superimposed on the identified CLSs (Table 5.2). Eleven Crop-Livestock Systems fall in the humid/sub-humid/coastal plain agro-ecologies, of which six have high rainfall-low irrigation (HR, LI); two each have medium rainfall-low irrigation (MR, LI) and medium rainfall-high irrigation (MR, HI) and one has high rainfall-high irrigation (HR, HI). Seven CLSs systems fall in the arid/semi-arid tropics, of which six are characterized by low rainfall-low irrigation (LR, LI) and one by low rainfall-high irrigation (LR, HI). This classification will be maintained throughout this chapter.

The Crop-Livestock Systems in the LR, LI arid/semi-arid tropics have the largest spread with a share of 43% in geographical area as well as net cropped

Table 5.1. Agricultural activity-based systems in a crop-livestock typology, India, 1998.

CLS[1]	No. of districts	Location (State)	Major agricultural activity and its share in total value of production (%)[2]
3.1	10	Himachal Pradesh (10)	Coarse cereals (21), wheat (18), buffalo (17) and cattle (13)
5.1	12	Madhya Pradesh (10) and Maharashtra (2)	Paddy (43), cattle (17), pulses (7) and buffalo (7)
5.2	11	Assam (10) and West Bengal (1)	Paddy (36), cattle (17), vegetables (9) and fruits (7)
5.3	11	Kerala (10) and Tamil Nadu (1)	Cattle (27), fruits (20), paddy (14) and vegetables (7)
8	16	Orissa (13) and West Bengal (3)	Paddy (54), vegetables (15), cattle (9) and pulses (5)
13	7	Uttar Pradesh (7)	Buffalo (19), cattle (17), wheat (15) and vegetables (10)
6	23	Madhya Pradesh (21), Rajasthan (1) and Maharashtra (1)	Soybean (31), wheat (19), pulses (11), cattle (7) and buffalo (7)
12	11	Madhya Pradesh (7) and Uttar Pradesh (4)	Wheat (27), pulses (20), cattle (13) and buffalo (11)
11	14	Gujarat (1), Haryana (1), Karnataka (1), Maharashtra (1) and Uttar Pradesh (10)	Sugarcane (32), wheat (14), buffalo (12) and paddy (9)
14	49	Bihar (17), Uttar Pradesh (21) and West Bengal (11)	Paddy (28), wheat (17), cattle (10) and vegetables (10)
1	21	Andhra Pradesh (9), Tamil Nadu (6), Karnataka (3) and Maharashtra (3)	Paddy (33), fruits (18), buffalo (10) and cattle (7)
2	10	Gujarat (10)	Groundnut (27), cotton (13), buffalo (10), cattle (7) and pearl millet (7)
3.2	9	Gujarat (2), Madhya Pradesh (1) and Rajasthan (6)	Coarse cereals (19), wheat (18), cattle (15) and buffalo (13)
4	16	Andhra Pradesh (5) and Karnataka (11)	Paddy (18), coarse cereals (12), cattle (12) and buffalo (8)
7	25	Gujarat (2), Karnataka (4), Maharashtra (18) and Madhya Pradesh (1)	Sugarcane (15), sorghum (14), cattle (11) and pulses (8)
10	27	Gujarat (2), Haryana (1), Rajasthan (19), Madhya Pradesh (3) and Uttar Pradesh (2)	Wheat (21), rapeseed and mustard (16), buffalo (13) and pearl millet (9)
15	10	Andhra Pradesh (6) and Tamil Nadu (4)	Groundnut (19), paddy (16), fruits (10), sugarcane (9) and cattle (9)
9	26	Haryana (5), Punjab (11) and Uttar Pradesh (10)	Wheat (34), buffalo (18), paddy (13) and sugarcane (5)

1. Crop-Livestock Systems.
2. Based on weighted mean value of all districts in the zone.
Source: District-level database.

area, and 31% in cattle-equivalent livestock population in the country (Table 5.3). These systems contribute nearly one-third of the value of agricultural output, both crops and livestock. In contrast, CLSs in the MR, HI humid zone share only 17% of the cropped area and account for 24% each of the value of crop and livestock outputs. The CLS in the LR, HI semi-arid tropics is most productive with only 8% share in the net cropped area as well as livestock population, but contribute 14% to crop output and 16% to livestock output. Crop-Livestock Systems also differ in socio-economic variables like population density, poverty, urbanization and

Table 5.2. Typology systems classified by Agro-Ecological Regions (AER), India, 1998.

Typology systems	Agro-Ecological Region (AER)	Normal rainfall (mm)	Gross irrigated area (%)
Humid (HR, LI)[1]			
3.1	Warm sub-humid	1472	18
5.1	Hot sub-humid to humid	1399	19
5.2	Hot/moist, dry sub-humid	2659	28
5.3	Hot moist sub-humid to humid	2801	16
8	Hot sub-humid	1504	27
13	Warm sub-humid	1597	16
Humid (MR, LI)[1]			
6	Hot sub-humid and semi-arid	1194	28
12	Hot sub-humid and semi-arid	1099	31
Humid (MR, HI)[1]			
11	Hot sub-humid (dry)	1133	68
14	Hot sub-humid (moist)	1331	53
Humid (HR, HI)[1]			
1	Coastal plain, hot sub-humid to SAT/hot pre-humid	1460	47
Arid and semi-arid (LR, LI)[1]			
2	Hot semi-arid	677	24
3.2	Hot semi-arid	767	29
4	Hot semi-arid	903	29
7	Hot semi-arid	850	17
10	Hot arid and semi-arid	625	34
15	Hot semi-arid	773	37
Semi-arid (LR, HI)[1]			
9	Hot semi-arid	812	87

1. LR = low rainfall, MR = medium rainfall, HR = high rainfall, LI = low irrigation, MI = medium irrigation and HI = high irrigation.

Table 5.3. Relative importance of systems in crop-livestock typology for selected indicators, India, 1998.

System	Geographical area	Cropped area	Human population	LU[1]	Crop value	Livestock value
	Share (%)					
3.1	1.25	0.40	0.64	1.08	0.47	0.82
5.1	5.78	5.28	3.52	5.86	2.60	3.53
5.2	3.01	2.07	2.81	2.95	1.78	2.03
5.3	1.49	1.68	3.66	1.13	1.79	3.08
8	6.59	5.46	6.91	8.17	7.37	3.92
13	1.71	0.33	0.53	0.90	0.29	0.71
6	5.54	7.03	3.86	4.82	6.02	3.93
12	2.57	3.09	1.98	2.97	1.74	2.26
11	3.14	3.95	5.06	4.18	7.76	5.71
14	12.74	13.19	24.68	22.47	16.47	18.38
1	8.85	6.25	9.21	7.20	7.84	7.77
2	4.71	4.25	2.93	2.25	3.61	2.74
3.2	2.91	2.25	1.95	3.43	1.83	2.88
4	5.71	5.09	5.42	4.81	3.71	4.82
7	11.16	14.44	8.17	8.45	10.08	9.43
10	12.17	13.10	6.32	7.34	8.23	7.85
15	5.82	4.62	4.91	4.34	4.66	4.25
9	4.83	7.52	7.44	7.65	13.78	15.88
All systems	**272**[2]	**140**[2]	**9,11,377**[3]	**2,79,636**[4]	**7,81,302**[5]	**2,21,759**[5]

Source: District-level database.

1. Livestock Units (cattle equivalent); 2. Million ha; 3. '000 numbers; 4. '000 units and 5. Million Rs.

land holding size and its distribution. Per capita land availability is low in most of the systems located in humid environments due to high population density. Smallholders are a dominant force in most Crop-Livestock Systems. Poverty incidence in CLSs 5.1, 5.2, 6, 8 and 14 in the humid region and 3.2, 7 and 15 in the arid/semi-arid tropics are above the national average. Incidence of poverty is the least in CLS 9 in the arid/semi-arid tropics (Table 5.4).

Table 5.4. Selected socio-economic indicators in Crop-Livestock Systems, India, 1998.

System	Population density (No./sq. km geographical area)	Urban population (%)	Per capita land [NCA (ha)/rural population]	Marginal and small farmers (%)	Per capita livestock (LU /rural population)[1]	Rural literacy (%)	Rural poor[2] (%)
3.1	171	9.4	0.1	83.7	0.6	59.9	7.4
5.1	204	18.9	0.3	71.7	0.6	42.2	38.8
5.2	313	12.8	0.1	80.9	0.4	44.9	30.6
5.3	824	31.7	0.1	68.8	0.1	82.0	9.8
8	351	18.1	0.1	87.2	0.4	48.3	29.8
13	105	19.4	0.1	90.6	0.6	53.7	6.5
6	234	34.2	0.4	55.8	0.6	35.9	26.8
12	259	25.0	0.3	70.9	0.6	33.6	18.8
11	541	28.8	0.2	82.4	0.4	37.0	9.1
14	650	15.8	0.1	89.9	0.3	32.8	25.2
1	349	32.4	0.2	85.9	0.3	46.8	17.2
2	209	45.0	0.4	48.1	0.4	51.4	6.8
3.2	225	16.6	0.2	63.3	0.6	30.4	24.4
4	318	40.3	0.2	76.2	0.5	40.3	17.9
7	245	28.8	0.4	57.6	0.4	46.2	24.8
10	174	26.1	0.4	49.8	0.5	33.8	9.4
15	283	24.2	0.2	79.0	0.4	41.9	35.6
9	516	28.2	0.2	73.7	0.4	42.3	6.7
All systems	**335**	**24.9**	**0.2**	**75.9**	**0.4**	**41.0**	**21.3**

1. LU = Livestock Unit (cattle equivalent).
2. Head count ratio.
Source: District-level database and GOI, Central Statistical Organization (CSO).

5.2. Characteristics of Crop-Livestock Systems

5.2.1. Relative Importance of Crops and Livestock

Crops on an average make up 75–80% of the gross value of agricultural production in India (Table 5.5). The only exceptions are systems 3.1, 5.3 and 13 in the HR, LI humid region and system 3.2 in the LR, LI arid/semi-arid tropics, where livestock contribute over 30% to agricultural output. CLSs 3.1 and 13 are found in higher altitudes, where livestock raising is one of the most important rural livelihood strategies. Here a large share of livestock feed comes from common grazing lands. CLS 5.3 is dominated by large ruminants, especially high-producing crossbred cows; commercial poultry is also an important activity. In contrast, CLS 3.2 dominated by coarse cereals, faces high risk of crop failure due to low and erratic rainfall. Farmers in this system thus depend on livestock for their livelihood. Milk is the most important livestock output, contributing 62% to the total value of livestock output in India (Table 5.6). The major share of milk comes from buffaloes. The relative share of buffaloes to cattle is higher in most systems, with a few exceptions in HR, LI humid environments. On an average, meat and eggs contribute approximately 15% to the livestock sector output, but with considerable inter-system variation. Their share is above average in systems 1, 5.1, 5.3, 8 and 14 in humid ecologies, and systems 4 and 15 in the semi-arid tropics. Poultry is the dominant meat in a number of systems both in humid environments and the arid/semi-arid tropics, except in systems 13 and 14 where small ruminants are the dominant suppliers. Draft animals contribute an average 12% to livestock output. They are more important in most humid ecologies. The share of draft power is low in CLSs with high irrigation. As expected, crop-livestock composition varies greatly even within an agro-ecological zone (Table 5.7). In most CLSs falling in the humid zone, agriculture is dominated by a few crops like paddy/wheat, fruits and vegetables.

Table 5.5. Relative importance of crop and livestock sub-sectors in India, 1998.

System	Agricultural value of production (million Rs.)	Share of crops (%)	Share of livestock (%)
3.1	5,464	66.6	33.4
5.1	28,179	72.2	27.8
5.2	18,375	75.5	24.5
5.3	20,800	66.8	33.3
8	66,284	86.9	13.1
13	3,825	58.7	41.3
6	55,768	84.4	15.6
12	18,611	73.1	26.9
11	73,264	82.7	17.3
14	1,69,415	75.9	24.1
1	78,457	78.0	21.9
2	34,268	82.3	17.7
3.2	20,638	69.1	30.9
4	39,645	73.0	26.9
7	99,659	79.0	20.9
10	81,720	78.7	21.3
15	45,823	79.4	20.6
9	142,862	75.4	24.7
All systems	**1,003,058**	**77.9**	**22.1**

Source: District-level database and GOI, Central Statistical Organization (CSO).

Table 5.6. Relative importance of livestock outputs in the livestock sub-sector[1], India, 1998.

System	All livestock value (million Rs.)	Milk: Cattle	Milk: Buffalo	Meat: Large ruminant	Meat: Small ruminant	Monogastrics: Meat	Monogastrics: Eggs	Draft power
		(% of livestock value)						
3.1	1,827	31.1	47.5	0	2.2	2	1.2	2.7
5.1	7,836	23	16	0.7	1.1	7	2.5	35.5
5.2	4,494	45.2	6.9	0.9	2.1	10.6	4.6	23
5.3	6,833	61.4	2.2	6.3	2.7	9.8	8.3	3.4
8	8,690	36.7	5.9	2.1	4.5	8.5	7	27.2
13	1,581	22.8	43.8	0.6	9.7	0.2	0.6	11.6
6	8,707	21.4	44.5	0.3	0.7	1.4	1.7	17
12	5,006	23.4	38.2	0.4	3.3	0.7	0.5	17.6
11	12,662	14.7	62.9	1	2.2	2	1.6	7.7
14	40,756	23.6	24.4	1.8	10.1	6.6	3.8	12.3
1	17,240	17.8	41	1.6	3.2	13.3	5.7	10.9
2	6,072	23.6	54	0.2	0.8	1.8	0.9	13.3
3.2	6,379	17.3	35.4	0.1	1.1	4.5	1.2	17.7
4	10,698	27.2	29.6	0.9	5.8	11.7	6.5	13
7	20,913	28.3	30.5	2.1	4.6	5.2	2.8	19.4
10	17,415	17.8	51.6	0.2	1.7	0.8	0.5	5.8
15	9,430	27.3	26.9	1.5	5.2	11.8	8.1	10.6
9	35,217	13.1	65.6	0.2	1.3	5.7	2	2.8
All systems	**2,21,756**	**23.2**	**38.0**	**1.2**	**4.1**	**6.3**	**3.4**	**12.3**

1.Figures do not add up to 100 since the share of wool, dung, etc., in total value are not shown here.
Source: District-level database and GOI, Central Statistical Organization (CSO), (2004).

On the other hand, in systems in the arid/semi-arid topics, crop production is more diversified with coarse cereals, pulses and oilseeds as important crops.

5.2.2. Livestock Population

On an average, there are about two cattle-equivalent livestock units per ha of cropped area in India (Table 5.8). The density is higher in most CLSs in the humid zone, except in systems 5.3 and 6. Within the humid zone, livestock density is the highest in CLSs 3.1 and 13 that have mountainous physiography and small cropped area. Livestock density is less in most CLSs in the semi-arid tropics, except 3.2. CLSs 2 and 10 have the lowest livestock density. By species, cattle density is the highest in humid zones, except in CLSs 6 and 11. Density of buffaloes is higher in irrigated CLSs. Sheep density in general is high in the semi-arid tropics while

Table 5.7. Relative importance of crops in the crop sub-sector, India, 1998.

System	All crops value (million Rs.)	Paddy	Wheat	Coarse grains	Pulses	Oil-seeds	Cotton	Sugar-cane	Fruits	Vegetables
		(% of crop value)								
3.1	3,636	6.0	27.1	31.3	1.0	0.9	0.0	0.6	15.7	15.2
5.1	20,343	59.4	3.6	3.3	10.3	5.9	0.6	0.6	3.4	5.2
5.2	13,881	47.6	1.9	1.2	1.5	4.4	0.0	4.3	9.1	12.4
5.3	13,967	21.8	0.0	0.0	0.3	0.3	0.2	0.5	31.6	11.7
8	57,594	62.2	0.2	1.3	5.6	3.8	0.1	2.0	3.6	18.0
13	2,244	16.0	25.2	3.9	1.9	1.9	0.0	3.6	5.8	16.6
6	47,061	1.3	22.6	4.7	13.0	39.9	1.3	1.0	4.1	2.4
12	13,605	5.1	37.2	4.5	27.7	10.9	0.0	0.6	3.1	3.8
11	60,602	11.0	16.6	2.2	2.3	3.7	0.3	38.7	7.5	4.6
14	1,28,659	37.2	22.0	3.2	4.3	1.9	0.0	4.5	8.5	13.0
1	61,217	41.9	0.0	2.1	3.8	5.2	3.1	6.9	23.4	3.6
2	28,197	3.8	6.3	10.1	2.7	39.1	16.1	1.6	3.4	4.8
3.2	14,260	5.2	25.5	30.0	13.1	13.6	1.9	1.2	0.6	1.2
4	28,947	24.0	0.6	21.3	4.6	13.0	5.3	9.6	4.2	6.1
7	78,746	3.2	3.8	21.8	10.7	12.3	8.0	18.7	8.9	6.4
10	64,306	1.0	26.6	13.7	8.7	25.1	3.7	0.9	1.0	2.3
15	36,392	20.3	0.0	4.7	3.0	27.7	3.5	11.9	12.5	8.3
9	1,07,646	17.4	45.1	4.5	1.6	3.3	4.0	6.0	4.0	5.8
All systems	**7,81,302**	**22.7**	**16.8**	**7.4**	**5.9**	**11.3**	**3.0**	**8.4**	**7.7**	**7.4**

Source: District-level database.

goat density is high in most CLSs in the humid zone. This difference in the geographical concentration of sheep and goats is largely due to their adaptability to different environments. Sheep are better adapted to the semi-arid and arid environments, while goats are adaptable to all environments. Socio-economic conditions also influence the distribution pattern/density of different animal species. Extremely small land holdings in the humid zones force farmers to own goats that require little initial investment and involve minor operational expenses.

Maps 5.2 to 5.6. reveal the changes that have occurred in the structure of livestock population over the last two decades (1982–1998). Cattle density remained stagnant, while buffalo density increased in a majority of the CLSs. The stagnation in cattle density was mainly due to a decline in its utility as a source of draft power in most CLSs. As a consequence, the ratio of female bovines to male bovines increased in several CLSs and remained constant in others. The ratio of cows to female buffaloes decreased in most CLSs, reflecting a shift towards buffaloes as the main source of milk. Only in CLS 5.3 did this ratio increase due to increasing population of crossbred cows. Sheep density increased in some CLSs and remained static in others. Goat density, on the other hand, showed an improvement in most CLSs. The ratio of bovines to ovines in general remained unchanged, but declined in CLSs 5.2, 11 and 14 in the humid region and CLSs 4 and 7 in the semi-arid tropics, primarily due to rapid population growth of the latter. Many factors have caused these changes. Decline in work animal density has largely been due to increasing mechanization of agricultural operations and expanding markets for machine services. In India, indigenous cows have mainly been raised to produce draft males. The milk yield of an indigenous cow is low, and with increasing mechanization of agriculture, the importance of indigenous cattle is likely to wane. Buffaloes are increasingly emerging as an important source of milk on account of consumer preference for high-fat milk and their better feed-conversion efficiency.

Table 5.8. Density of bovines, ovines and their relative importance, India, 1998.

System	Cattle/ha (NCA)[1]	Buffalo/ha (NCA)	Sheep/ ha (CPR)[2]	Goat/ha (CPR)	LU[3]/ha (NCA)	Adult female bovine to adult male bovine	Adult female cattle to adult female buffalo	Bovine to ovine
3.1	3.9	1.3	0.8	0.8	5.4	1.5	1.5	1.3
5.1	1.9	0.4	0.1	1.5	2.2	0.7	5.0	4.1
5.2	2.9	0.3	0.2	7.4	2.8	1.1	12.0	3.0
5.3	1.5	0.1	0.1	14.3	1.3	9.6	26.3	1.9
8	2.8	0.3	1.4	6.1	3.0	0.8	10.6	2.1
13	4.0	1.4	0.7	2.2	5.4	1.4	1.4	1.7
6	1.1	0.4	0.1	1.7	1.4	1.4	1.6	3.7
12	1.5	0.5	0.4	2.0	1.9	1.3	1.7	3.2
11	0.9	1.3	2.3	4.7	2.1	1.8	0.4	3.1
14	2.3	0.7	1.0	7.8	3.4	1.0	1.9	1.4
1	1.4	1.0	1.5	1.4	2.3	1.7	0.9	1.6
2	0.6	0.5	0.6	0.9	1.1	2.4	0.7	1.6
3.2	1.9	1.1	1.4	3.1	3.0	1.3	0.9	1.2
4	1.3	0.5	2.2	1.2	1.9	1.5	1.5	1.2
7	0.8	0.3	1.3	3.2	1.2	1.4	1.6	1.4
10	0.5	0.6	1.6	1.8	1.1	5.6	0.7	0.8
15	1.3	0.6	2.4	1.5	1.9	1.4	1.3	1.0
9	0.7	1.5	2.6	5.5	2.0	3.9	0.3	4.2
All systems	**1.4**	**0.6**	**1.3**	**2.8**	**2.0**	**1.4**	**1.4**	**1.6**

1. NCA = Net Cropped Area.
2. CPR = Common Property Resources (80% cultivable waste + permanent pastures + 90% other fallows + 90% current fallows).
3. LU = Livestock Unit (cattle equivalent).
Source: District-level database.

5.2.3. Output Growth

Between 1982 and 1998, on average, growth in the crop sector was marginally higher at 2.7% per annum compared to 2.2% in the livestock sector (Table 5.9). However, excluding draft power output, the livestock sector showed an impressive growth of 4% per annum. Except in CLS 5.3, the crop sector performed well.

Paddy is a dominant crop in CLS 5.3; however the poor performance of the crop sector was due to a decline in area under paddy. Oilseeds and cotton output improved in most CLSs. Production of coarse cereals remained stagnant in most. Lack of policy support for coarse cereals led to large-scale substitution of area under coarse cereals (Gulati and Kelley 1999). This has implications for the livestock sector, as coarse cereals are an important source of feed and fodder. One consequence of this stagnation in output in recent years has been a quick

Table 5.9. Growth (% per annum) in the value of production of agriculture, crop and livestock sectors, India, 1982–1998 (1982 constant prices).

System	Crop + livestock	Crop	Livestock[1]	Livestock[2]
3.1	1.6	1.5	1.9	3.9
5.1	1.8	2.0	1.4	2.6
5.2	1.8	1.5	2.9	4.1
5.3	0.9	-0.1	3.7	5.0
8	2.0	2.1	1.2	4.4
13	0.8	0.9	0.6	2.1
6	4.6	5.3	1.6	3.2
12	2.3	2.8	1.2	2.9
11	3.1	3.2	2.4	4.3
14	2.3	2.4	1.8	4.0
1	2.0	1.8	2.7	4.4
2	2.2	2.3	1.8	4.4
3.2	2.9	3.9	1.2	4.0
4	1.9	1.6	2.9	5.2
7	3.0	3.1	2.8	4.6
10	3.7	4.3	1.8	3.5
15	2.7	2.8	2.4	4.1
9	2.9	2.8	3.0	4.0
All systems	**2.6**	**2.7**	**2.2**	**4.0**

1.Value of draft power included in total value.
2.Value of draft power excluded from total value.
Source: District-level database.

increase in the price of straw compared to that of grains (Kelley et al. 1993 and Kelley and Parthasarathy Rao 1996).Within the livestock sector, higher growth was observed in milk and meat production than in draft power and manure. On the whole, milk production grew at an annual rate of 4.3%. In CLSs 5.3, 7 and 8, milk output grew by over 5% a year, while in systems 1, 4, 5.2 and 11, it was closer to 5%. Meat production witnessed an annual growth of about 5% on average, but with significant variations across CLSs, unlike milk. It grew at a rate of over 6% in eight CLSs cutting across agro-ecologies, and largely came from poultry. Likewise, growth in egg production was also higher in CLSs with high growth in meat. Rapid growth in animal-based food is mainly demand-driven and reflects widespread changes in food consumption patterns (Kumar and Mathur 1996). Recent studies by Delgado et al. (1999) and Paroda and Kumar (2000) have found that the income elasticity of demand for livestock products is higher than that for cereals and pulses. Draft power during this period was under stress, as is reflected in the significantly negative (-4.1) growth rate. This phenomenon is universal, but stronger in CLSs 3.1, 5.3, 13, 11 and 14 in the humid zone, and CLSs 3.2, 9 and 10 in the semi-arid tropics. Overall, dung production increased, but marginally.

5.2.4. Input Use and Technology

Seeds and Fertilizers: There is considerable variation in input use and technology adoption across CLSs in both the humid and arid/semi-arid tropics (Table 5.10). The proportion of cropped area irrigated and fertilizer use intensity is the highest in CLS 9 in the semi-arid tropics, followed by CLSs 11 and 14 in the humid zone. Fertilizer use intensity is low in systems falling in the MR, LI humid region. The area under high-yielding crop varieties is higher in most systems in the humid zone. The number of tractors and electric and diesel pumps per ha varies greatly across CLSs, irrespective of their agro-ecologies. Increasing use of modern inputs and machines have led to significant improvements in crop yields, but these tend to promote monocropping, encourage excess withdrawal of groundwater and lead to a decline in crop-livestock interactions (Kumar et al. 1999 and Pingali and Shah 1999).In irrigated Crop-Livestock Systems, progressive replacement of draft animals by electrical and mechanical sources, diminishing reliance on dung as manure and on crop residues as fodder and burning of rice straws have upset the traditional symbiotic interactions between crops and animals. For example, in Punjab under the LR, HI semi-arid tropics, the use of chemical fertilizer has reached 260 kg per ha, exceeding the recommended dosage. On the other hand, use of organic manure has drastically declined over the last few decades (Kumar et al. 1999). The use of dung as manure has declined due to labor shortage and the reluctance of family members to transport it from homesteads to fields (Sidhu et al. 1998). The decline in draft animal power use is on account of its substitution by mechanical and electric power.

Table 5.10. Input use in the Crop-Livestock Systems, India, 1998.

System	Irrigated area (%)	Fertilizer consumption (kg/ha)	Area under high-yielding cultivars (%)	Density of tractors (per '000 ha)[1]	Density of electric and diesel pumps (per '000 ha)
3.1	18.4	53.2	55.0	4.6	4.5
5.1	19.4	44.5	41.7	1.6	13.2
5.2	27.5	32.9	37.0	0.2	4.9
5.3	15.8	92.1	28.6	0.9	118.8
8	26.8	80.8	38.4	1.3	26.6
13	15.6	14.5	59.2	2.4	0.7
6	27.9	74.5	20.0	5.4	74.3
12	30.8	39.9	28.5	9.4	51.3
11	68.1	212.6	28.3	28.9	148.6
14	52.6	126.8	34.3	6.9	104.5
1	47.2	183.6	44.8	5.6	111.0
2	23.6	73.3	20.5	5.7	75.0
3.2	28.5	74.7	23.6	5.6	88.3
4	29.4	141.8	37.9	4.1	81.7
7	16.9	74.3	37.1	2.6	43.7
10	34.4	53.7	18.4	10.2	47.4
15	36.9	134.2	20.3	4.3	179.4
9	87.1	247.2	63.1	34.7	151.8

1. Per '000 ha of Net Cropped Area (NCA).
Source: District-level database.

Feed and Nutrition: Estimating feed demand is challenging given the lack of information on quantities of agricultural commodities used as feed. Here we have assumed that feed demand is synonymous with its availability, and hence prepared an inventory of feed resources by estimating the availability of crop residues; grasses from common lands/pastures; forage production from cultivated fodder crops; and Agro-industrial By-products from cereals, pulses and oilseeds using standard conversion factors from the literature (Appendix 5.2). Top feeds have not been included in this inventory due to non-availability of data. Such an inventory aids in ascertaining the appropriate number and composition of animals in a given location in relation to available feed and the type of interventions needed to address feed constraints to maximize production of livestock products. Average feed availability from all sources on dry matter basis is 1.6 t per cattle-equivalent livestock unit. However, there is considerable variation in feed availability across Crop-Livestock Systems (Table 5.11 and Map 5.7). It is lower in most systems in the humid region with the exception of CLSs 11 and 13. In general, the feed situation is better in most CLSs in the semi-arid tropics. It is estimated to be high in CLS 9.

Crop residues are the most important source of feed. On an average, they account for 64% of the total feed and fodder across systems. Crop residues comprise less then 26% of total feed in CLSs 5.3 and 13 in the humid region, where grasses from grazing lands comprise more than 70% of the feed. The contribution of grasses from grazing lands is relatively lower in the CLSs in the semi-arid tropics. Fodder from forage crops is important in irrigated CLSs with a few exceptions. The share of forage crops in total feed is the highest in CLS 2, followed by CLSs 9 and 10 in the semi-arid tropics. Incidentally, CLS 2 has low-level irrigation and a higher share of forages in feed. CLS 2 is located in Gujarat state which has a wider network of dairy co-operatives which provides farmers with easy access to output markets, that acts as an incentive to grow forage crops for better productivity. This implies that institutional factors also play an important role in adoption of forages even in rainfed environments. Grains and Agro-industrial By-products (AIBPs) such as brans and oilcakes on an average make up 6.7% of the total feed on dry matter basis. In CLSs 2, 6, 9, 10 and 12, their share is more than the average. However, AIBPs appear to be more important in the semi-arid tropics because of the larger production of oilseeds and pulses[4].

The availability of grazing lands in forests, pastures, grassland and uncultivated arable land has been declining (Jodha 1992 and World Bank 1996), partly reflecting the encroachment on forests, pastures and public lands by a rapidly growing population, and the redistribution of common lands under poverty alleviation programs. The availability of grasses from these lands has also declined due to a decline in their productivity. The intensity of these phenomena and their impacts could vary across CLSs and would exert a more negative impact on ovines than on bovines and in CLSs with nomadic and transhumance characteristics. Over

[4] Crop residues, grasses and forage crops are utilized in the same area/district where they are produced. This is not the case with AIBPs. While it is easier to estimate the production of AIBPs, their availability in the place of production is not assured. They are generally traded across district/state boundaries (oilseed cakes are exported), and also used as poultry feed in urban areas. Hence, the availability of AIBPs should be viewed with caution.

the last two decades, the feed situation appears to have improved in 9 CLSs, deteriorated in 3 CLSs and remained almost unchanged in others, as is indicated by the changes in feed availability per livestock unit. In general, the extent of improvement was higher in CLSs in the humid region. Besides quantity, quality of feed is crucial in determining livestock productivity. Although this study has

Table 5.11. Availability of feed / fodder and its composition, India, 1998.

	Total feed and fodder[1] (t /LU[2])		Proportion to total feed and fodder			
System	1982	1998	Crop residue	Grasses	Green fodder	AIBP
3.1	0.86	1.39	45.6	50.0	1.7	2.7
5.1	1.71	1.20	45.0	50.6	0.04	4.4
5.2	1.33	1.28	45.2	50.6	0.1	4.1
5.3	1.67	1.45	26.3	71.3	0.2	2.2
8	1.13	1.13	61.0	33.38	0.02	5.6
13	2.49	2.13	13.8	84.1	0.8	1.3
6	1.76	2.05	52.6	16.8	16.1	14.5
12	1.13	1.26	62.9	23.4	6.4	7.4
11	2.65	4.05	78.6	5.2	13.2	3.0
14	0.94	1.11	72.8	19.4	1.5	6.3
1	1.73	1.98	53.1	35.6	6.7	4.5
2	1.84	2.31	46.3	11.0	29.3	13.4
3.2	0.85	1.14	63.8	20.3	9.4	6.4
4	1.50	1.70	67.8	25.7	1.3	5.1
7	2.05	2.27	77.6	11.4	5.4	5.6
10	1.50	1.94	62.0	9.4	18.1	10.5
15	1.37	1.76	64.6	22.7	4.9	7.7
9	3.39	3.67	66.2	2.4	24.0	7.4
All systems	**1.57**	**1.81**	**64.1**	**19.2**	**10.0**	**6.7**

1. Includes crop residues, grasses from grazing lands, green fodder crops and AIBPs on dry matter basis.
2. LU = Livestock Unit (cattle equivalent).
Source: District-level database.

not converted quantity into qualitative parameters like Total Digestable Nutrients (TDN) and Digestible Crude Protein (DCP), some general observations about quality can be made based on feed type. For example, straw from coarse cereals is more nutritious than that from slender cereals (Singh and Prasad 2002). The decline in production of coarse cereals as observed previously should have adversely affected the quality of feed in the semi-arid tropics, where coarse grains are the major crops grown. Though a number of technological options such as making of hay/silage and urea-ammoniation, and urea-molasses treatment of straw and urea-molasses exist, their extremely low adoption in all CLSs is partly because of a lack of their demonstrable benefits and non-awareness among farmers. These can however be promoted in farming systems where conditions are conducive to their success (Chesson and Orskov 1984; Devendra 1997 and Ghebrehiwet et al. 1988). A long-term option is the genetic enhancement of the digestibility coefficient of coarse cereal straws. In the Indian context, Kristjansen et al. (1999) found that a 1% increase in digestibility of sorghum and pearl millet straw resulted in 4–5% increase in milk and meat yields.

Crossbreeding: Strategic interventions for genetic enhancement of livestock, particularly cattle and buffaloes, is most critical for improving livestock productivity and sustainability. Crossbreeding of low-yielding indigenous breeds with high-yielding exotic breeds is a useful strategy to improve milk and meat yields. The performance of crossbred cows is distinctly superior to that of local breeds in India. Crossbred cows that account for 10% of the total milch cows, contribute more than one-third of total cow milk production (Birthal et al. 2003). Despite this, potential adoption of crossbreeding technology remains low except in CLSs 5.3 and 9 (Table 5.12 and Map 5.8). Adoption rates are better in CLSs 1, 3.1, 5.3, 7, 9, 11 and 15. Feed deficit (particularly concentrates and green fodder), harsh agro-climatic conditions, poor veterinary services, etc. have led to poor adoption of crossbreeding technology in some CLSs.

The technology has failed to take off in larger areas due to its introduction without taking into consideration the agro-climatic and socio-economic constraints of the region.Buffaloes have by and large not been part of artificial insemination. However, efforts are on in some regions to upgrade low-yielding breeds using superior Murrah breed. Murrah buffaloes are now however under severe negative selection pressure, as the best genotypes born each year are lost to the cities for milk production; and slaughtered after becoming dry, thereby perpetuating a steady genetic drain from the population. Currently, there is a need to increase resources devoted to research on improving the milk-yielding capacity of buffaloes (Birthal et al. 2002).

The adoption of crossbreeding technology in sheep is low; only about 3% of the sheep in the country are crossbreds. Adoption rate is higher in some pockets of the humid region. Sheep and goats are short-generation interval animals requiring little initial investment. Being prolific breeders, they generate quick returns to investment. Small ruminants are thus most suitable for households having no access to land and employment opportunities. Despite this, the adoption of improved breeds is low, and meat yield of small ruminants has been stagnating. There could be several factors responsible for low adoption, such as lack of access to delivery services, feed and fodder scarcity and sparse local markets for their products (Birthal et al. 2003 and Pasha 2001). Lack of institutional support and deteriorating grazing lands act as disincentives to small-scale producers rearing crossbred animals, though there is ample scope to improve the productivity of short-generation animals such as sheep and goat. Conservation and management of common grazing lands through legislative means (protection from encroachments and ban on acquisition and redistribution of common lands under rural development programs) and improving community participation in the management of common lands would help improve poor households' access to grazing resources at little cost.

The average share of improved chicken to total chicken across all systems is 38%. But, there is considerable variation in adoption rates across different CLSs (Table 5.12). The share of improved chicken to total chicken is 50% or above in CLSs 2, 3.1, 4, 5.3, 11, 13 and 15. Urbanization is an important driving force in poultry production. The private sector has entered the poultry sector in a big way, thereby providing access to the latest technologies.

Table 5.12. Species-wise adoption (%) of improved breeding technology, India.

System	Cattle (crossbred) 1997	Sheep (crossbred) 1992	Pig (crossbred) 1992	Improved chicken to total poultry 1992	Improved chicken to total chicken 1992
3.1	19.9 (8.5)[1]	6.7 (3.1)	17.7 (-6.3)	21.6 (14.8)	74.5
5.1	1.4 (14.0)	1.0 (7.3)	1.1 (-1.1)	5.2 (15.7)	11.2
5.2	5.3 (6.0)	4.3 (-1.0)	15.2 (3.9)	5.7 (6.6)	13.8
5.3	67.1 (4.7)	27.1 (9.9)	32.4 (14.7)	15.2 (7.5)	55.5
8	8.1 (9.4)	1.2 (-9.5)	2.0 (-10.0)	10.2 (18.4)	24.2
13	6.7 (2.0)	15.8 (-2.8)	13.6 (-5.9)	15.5 (7.5)	49.8
6	2.3 (12.9)	4.8 (14.3)	1.8 (5.3)	11.0 (23.7)	29.2
12	0.4 (1.9)	0.4 (-7.5)	2.8 (1.1)	7.7 (12.8)	25.4
11	18.3 (-2.8)	3.4 (4.3)	15.0 (0.8)	24.8 (25.3)	61.7
14	4.7 (-0.4)	3.7 (1.8)	9.4 (5.8)	4.3 (9.6)	12.9
1	10.4 (7.4)	3.2 (0.7)	10.6 (6.3)	14.7 (17.7)	36.1
2	6.4 (11.3)	0.6 (-8.9)	0.7 (-12.5)	27.2 (23.6)	67.7
3.2	2.2 (10.5)	0.4 (-1.2)	5.8 (7.7)	3.9 (9.0)	9.2
4	10.9 (1.6)	2.7 (0.6)	9.8 (6.7)	18.9 (11.8)	51.0
7	19.2 (14.1)	1.4 (2.2)	6.0 (-0.1)	13.4 (13.4)	35.0
10	3.3 (12.3)	0.6 (6.6)	9.2 (8.9)	10.0 (12.0)	35.0
15	15.7 (8.5)	1.7 (-5.1)	2.6 (-0.7)	19.5 (13.6)	49.4
9	38.1 (1.3)	18.1 (2.5)	29.9 (4.6)	40.6 (16.0)	84.7
All systems	**9.8 (5.5)**	**2.6 (1.7)**	**10.8 (5.4)**	**14.6 (16.0)**	**38.3**

1. Figures in parentheses are annual compound growth rates for the last 10 years.

5.2.5. Infrastructure

Markets and infrastructure facilitate growth by providing farmers easy access to services and cut down on transaction costs. Market density is low in all CLSs in the semi-arid tropics[5] (Table 5.13). In the humid zone, market density varies – CLSs 5.2 and 9 have a relatively better network of markets. Road density varies across CLSs, between 0.2 to 1.0 km/sq. km of geographical area. Veterinary services are relatively better in CLSs 3.1, 5.3, 9 and 13. Improved access to animal health and breeding services is particularly important in the adoption of crossbreeding technologies and disease management. Disease surveillance and monitoring systems are weak in most CLSs, and preventive disease measures receive little attention. India's dairy co-operatives are widely acclaimed for their success in linking millions of dairy farmers to markets. But, the success has varied. The intensity of dairy co-operatives measured as the number of dairy co-operatives per 1000 livestock units is the highest in CLSs 2, 5.3 and 9, indicating that dairy farmers there have better access to milk markets.

Table 5.13. Density of infrastructure and veterinary institutions, India, 1998.

System	Market density (no./10000 sq.km of geographical area)	Road density (km/sq. km of geographical area)	Veterinary (hospital + dispensary) (no./'000 LU)[1]	No. of dairy co-operatives (no./ '000 LU)
3.1	21.3	0.6	0.35	0.06
5.1	14.8	0.4	0.08	0.11
5.2	86.0	0.4	0.04	0.01
5.3	35.9	0.6	0.32	0.72
8	14.3	1.0	0.03	0.15
13	9.7	0.3	0.28	0.25
6	20.1	0.2	0.08	0.11
12	17.6	0.3	0.08	0.11
11	34.4	0.4	0.11	0.25
14	16.5	0.5	0.06	0.12
1	24.4	0.7	0.09	0.49
2	13.3	0.3	0.07	0.85
3.2	21.3	0.3	0.06	0.44
4	25.5	0.8	0.07	0.42
7	25.7	0.5	0.05	0.36
10	13.3	0.2	0.09	0.20
15	19.8	0.8	0.08	0.49
9	69.4	0.6	0.19	0.60
All systems	**21.9**	**0.5**	**0.09**	**-**

1. LU = Livestock Unit (cattle equivalent).
Source: District-level database.

[5] Markets included in this study are regulated market yards that mainly deal with crops. However, since they are located in nearby towns, input dealers, fodder markets, concentrate feeds, etc. are available. Hence, regulated markets are included as a proxy for livestock products, feed and input markets.

5.2.6. Productivity[6]

Table 5.14 shows productivity in the crop and livestock sectors in Crop-Livestock Systems in India. CLS 11 has the highest level of crop productivity, closely followed by CLS 9. Incidentally, both these zones have sugarcane, wheat, buffalo and paddy as common agricultural commodities though these differ in relative importance. CLSs 8, 3.1, 1 and 14 are next in order. CLS 5.1 has the lowest crop productivity followed by CLSs 12 and 10. These zones are characterized by low and erratic rainfall, with rainfed rice, wheat and coarse cereals being the important crops.

The productivity of Indian livestock is low, but varies substantially across CLSs. Average livestock productivity per cattle equivalent unit is the highest in CLS 5.3 dominated by cattle[7] . It is also on the higher side in CLSs 9 and 11, which are dominated by buffaloes. The main reasons for the high productivity include the dominance of high-producing breeds, better availability of feed, dominance of female bovines and a better network of dairy co-operatives and veterinary institutions. It may be recalled that these CLSs have one of the highest proportion of crossbreds in cattle population, and the Murrah breed dominates in the buffalo-dominated CLSs 9 and 11.

Crop-Livestock Systems 5.1, 5.2 and 8, all in the humid zone, have low livestock productivity. These systems have a high prevalence of indigenous cattle, low female to male bovine ratio and low availability of feed per livestock unit. Quality of feed is also poor as most of the demand is met from paddy straw and common grazing resources. There is a close correspondence between crop productivity and livestock productivity. The correlation coefficient between the two is 0.5, which is statistically significant at 5% level. Thus districts with high crop productivity also have high livestock productivity. Hence, feed availability is an important input for increasing livestock productivity. There are, however, a few exceptions. CLSs 7 and 10 (in the semi-arid tropics) have low crop productivity but high livestock productivity due to the dominance of crossbred cows, low livestock density, the dominance of food-feed crops in the cropping pattern and better feed availability per livestock unit. On the contrary, CLSs 3.1, 8 and 14 (in the humid zone) have high crop productivity but low livestock productivity. This is due to high livestock density, low feed availability per livestock unit and dominance of draft animals.

[6] Unlike in crops, no data is available on productivity of livestock outputs at the district level. Using the value of production of livestock species (from state-level data) and livestock numbers, we estimated productivity at the system or zonal level. Productivity data should therefore be read cautiously, its main purpose being to give an indication of relative differences in productivity between species across zones.

[7] In the previous section, feed availability in the system was found to be low since data on area under fodder crops is not available, although large areas are devoted to improved grasses such as Stylosanthes, (Personal communication, CR Ramesh, IGFRI, Dharwad). Secondly, the abundant availability of *coconut poonac* (coconut cake) has not been included in our estimation of feed availability from AIBPs

Table 5.14. Productivity of livestock species, India, 1998 (1980–81 constant prices).

System[1]	Livestock[2] (Rs./LU)	Crop (Rs./ha)	Cattle[2]	Buffalo[2]	Sheep	Goat	Poultry	Pig
			(Rs./animal/annum)					
5.3	2,164	5,940	1,761	1,608	69	188	44	131
9	1,645	10,205	972	1,447	59	290	146	81
11	1,082	10,936	644	109	60	155	38	133
2	966	4,725	710	1,070	33	62	50	15
7	886	3,889	668	994	85	96	50	79
1	856	6,987	494	834	55	55	60	29
10	848	3,501	650	892	20	76	76	94
4	796	4,056	528	784	66	81	67	62
15	777	5,617	542	705	53	51	69	16
3.2	666	4,523	514	729	18	67	77	87
14	649	6,952	425	615	60	165	51	195
6	646	4,770	410	996	84	97	61	24
13	630	4,861	380	976	71	126	24	181
12	603	3,138	403	862	76	179	30	88
3.1	603	6,519	354	1,037	47	56	62	290
5.2	545	4,778	448	480	40	73	33	59
5.1	478	2,746	377	516	84	82	69	21
8	380	7,517	307	298	90	43	38	75
All systems	**793**	**5,570**	**509**	**913**	**51**	**115**	**58**	**113**

1. Sorted on livestock productivity (Rs. / LU).
2. Including draft power value.

5.3. Factors Influencing System Dynamics

The analysis in the previous section shows that mixed Crop-Livestock Systems are diverse structurally as well as in performance due to differences in underlying factors related to agro-ecology, technology, socio-economics and infrastructure. However, it is difficult to ascertain their relative contribution to system dynamics and productivity. To better understand their relative importance, econometric models were estimated to explain (i) intensification of livestock systems; (ii) adoption of crossbreeding technology; and (iii) crop and livestock productivity. The analysis was carried out using district-level information for 1998. The Seemingly Unrelated Regression Estimation (SURE) technique, due to Zellner (1962) was used to explain spatial differences in livestock intensification at the species level. The SURE model assumes that in many situations not all sets of equations are determined simultaneously. Instead, several equations may be connected not because they interact but because their error terms are related. In such cases, estimating the equation as a single set should improve efficiency by allowing contemporaneous correlation between the error terms across the equations.The Ordinary Least Squares method (OLS) was used to identify factors influencing the adoption of crossbreeding technology and crop and livestock productivity. Both log and linear forms were tried, and the better estimates of the two are reported. Estimation problems due to multicollinearity and heteroskedasticity have been addressed. Data have been corrected for heteroskedasticity by dividing each observation by the square root of the estimated variance of the disturbance term. For linear models, the elasticities of the coefficients were calculated using appropriate formulae. Several variables among the independent variables were correlated. Only one of the variables was used in the model as a proxy for the rest. The list and description of explanatory variables considered for the multivariate analysis are shown in Table 5.15.

Table 5.15. Explanatory variables used for the multivariate analysis.

Explanatory variables (determinants)	Description of variables	Unit of observation
POPDEN	Human population density (rural)	No./sq. km of geographical area
URBPER	Urban population to total population	%
FSIZE	Size of land holding	Ha
MSFPER	Marginal and small land holdings to total holdings	%
RAIN	Normal rainfall	mm
CVRAIN	Monthly rainfall distribution	Coefficient of variation (%)
IRRI	Gross irrigated area to total cropped area	% to crop area
TRACT	Tractors per ‘000 ha of NCA	No./’000 ha of NCA
GRAZE	Feed availability from grazing lands	t / livestock units (LU)
FEED	Total feed + fodder on dry matter basis	t / livestock units (LU)
CPRGA	Common property resources to geographical area	%
VETY	Veterinary institutes per ‘000 LU	No./’000 LU
MARKET	Density of regulated markets	No./10000 sq. km of geographical area
ROAD	Density of total road length	Km/sq. km of geographical area
LSHOLD	Livestock per land holding	No.
SHSIZE	Sheep per land holding	No.
PGSIZE	Pigs per land holding	No.
PLSIZE	Poultry per land holding	No.
LUDEN	Density of livestock units	No./ha
WORKAN	Density of work cattle	No./ha
CBCATL	Crossbred cattle	No.
CBSHEP	Crossbred sheep	No.

5.3.1. Intensification

The theory of intensification states that agricultural intensification occurs in response to increasing population pressure on land (Boserup 1965, 1981 and Ruthenberg 1980). Decreasing land availability induces producers to adopt new technologies and integrate livestock into cropping activities for increased returns to land. In the context of the Crop-Livestock System, McIntire et al. (1992) have shown that interaction between crop and livestock is weak at low population density. It increases with increase in population density and finally declines, giving way to specialized crop and livestock activities. However, the overwhelming importance of population density in the process of agricultural intensification has been questioned (Gass and Sumberg 1993; Adams and Mortimore 1997 and Williams et al. 2000). In the context of livestock, it is argued that growth in demand for animal-based foods (driven by income growth and urbanization), improvements in markets and infrastructure and intraregional trade are also important drivers of intensification.

We define intensification as livestock population per unit of arable land i.e., stocking rate[8]. Considerable variation exists in the intensification of livestock production across agro-climatic regions, indicating that agro-ecological factors such as rainfall and length of growing period could be important determinants of intensification. Besides, a number of other factors related to demography (population density and urbanization); production technology (high-yielding crop varieties, fertilizer use, mechanization, irrigation and crossbreeding); feed and fodder availability; socio-economic environment (farm size and incidence of smallholdings); and infrastructure (roads, markets and veterinary infrastructure) could also be important determinants of intensification. Their influence, however, would vary for different species.

We hypothesize that (i) intensification increases with increase in demand for animal-based foods; (ii) intensification is greater in areas with high population density dominated by smallholders; (iii) infrastructure development promotes livestock intensification by establishing linkages between rural production and urban consumption; and (iv) intensive cultivation practices discourage intensification of dairy cattle due to substitution of draft animal power with mechanical power. Also, there is expected to be less intensification of small ruminant production in intensively cultivated areas due to less land under grazing and fallows, and (v) climate has a differential effect on intensification of different species because of the differences in their biological adaptability.

[8] Livestock intensification can also be measured as the ratio of livestock population to human population or feed use per livestock unit. The latter, however, is more appropriate as it reflects animal productivity better. However, in mixed farming systems where animals are largely dependent on crop residues and grazing, information on feed use is scarce.

Some of these factors could be highly correlated; hence the variable that is directly relevant to a species has been included. Besides, regional dummies have also been included in the model with districts in the arid region taking a value of 0 and others 1[9].

In Table 5.16, equation 1 examines the effect of the determinants on the intensification of all livestock (in terms of standardized LU) and then proceeds to individual species i.e., equations 2 to 6. As expected, human population density has a positive and significant effect on overall intensification. This gives credence to the 'intensification theory', which states that intensification occurs in response to increasing human population density. The role of urbanization in intensification is quite strong, implying demand-led intensification. Coefficient of landholding is negative and significant, suggesting higher intensification of livestock on smallholdings. The effect of other variables is not significant due to heterogeneity in the production systems; however, these could be important in species-specific intensification.

Both human population density and urbanization have positive and significant effects on intensification of dairy cattle. The effect of landholding is negative, as expected. However, intensification of dairy cattle declines with increase in irrigation level due to replacement of draft cattle by machines. A positive and significant sign of rainfall in the dairy and draft cattle equation and a negative sign of tractors in the draft cattle equation substantiate this. These findings imply that intensification of cattle production is declining with rising intensification of agriculture.

Intensification of dairy buffalo declines with increase in human population density. The effect of urbanization is positive and significant. The low intensification of dairy buffalo in densely populated areas is due to several interrelated factors. Unlike cattle, buffaloes require better feeding both in terms of quantity and feed quality. Incidentally, the densely populated areas are in the eastern region (Bihar, Orissa and West Bengal) which have high rainfall, with *kharif* rice as the dominant crop (60% of the gross cropped area). Fodder crops like sorghum, pearl millet, maize and finger millet account for only 3% of the area under cultivation. Irrigation, however, promotes intensification of dairy buffalo due to its positive effect on feed availability. Intensification of buffalo is also associated with smallholders. The effect of density of roads is positive and significant.

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[9] The regional dummies broadly correspond to the agro-ecological classification of Crop-Livestock Systems. Thus in Table 5.2, districts falling under the humid zone have been sub-divided into hill and mountain and irrigated districts. Rainfed includes all the districts falling in the semi-arid tropics.

Table 5.16. SURE estimates of the factors influencing livestock intensification, India, 1998.

Explanatory variables[1]	Livestock units (Eq. 1)	Dairy cattle (Eq. 2)	Draft cattle (Eq.3)	Dairy buffalo (Eq. 4)	Goat (Eq. 5)	Sheep (Eq.6)
	Dependent variable: Stocking rate (No./ha of Net Cropped Area)					
POPDEN	0.0007*** (0.0003)[2]	0.0004*** (0.0001)	-	-0.0001* (0.0001)	0.0018*** (0.0003)	-0.0002 (0.0002)
URBPER	0.0130*** (0.0027)	0.0046*** (0.0009)	-	0.0017* (0.0009)	0.0075*** (0.0029)	0.0033* (0.0020)
FSIZE	-0.2619*** (0.0611)	-0.0344** (0.0152)	-0.0836*** (0.0190)	-0.0210* (0.0113)	-	-
MSFPER	-	-	-	-	0.0084** (0.0035)	0.0054** (0.0022)
RAIN	0.0030 (0.0151)	0.0100*** (0.0036)	0.0030 (0.0045)	-0.0149*** (0.0024)	-0.0081 (0.0104)	-0.0192*** (0.0060)
CVRAIN	-0.0018 (0.0039)	-0.0012 (0.0009)	0.0011 (0.0012)	0.0024*** (0.0007)	-0.0016 (0.0027)	-0.0077*** (0.0015)
IRRI	-0.0015 (0.0025)	-0.0028*** (0.0008)	-	0.0050*** (0.0007)	-0.0130*** (0.0024)	0.0020 (0.0016)
TRACT	-	-	-0.0093*** (0.0014)	-	-	-
CPRGA	-	-	-	-	-0.0026 (0.0047)	0.0334*** (0.0035)
ROAD	-0.0011 (0.0012)	0.0002 (0.0004)	-	0.0007* (0.0004)	-0.0015 (0.0013)	-0.0003 (0.0009)
Region dummies						
Coastal	-0.4341*** (0.5746)	-0.0786** (0.1341)	-0.0948 (0.1750)	0.2425*** (0.0909)	-1.1152*** (0.3526)	-0.7217*** (0.1957)
Hill and mountain	2.1104 (0.6645)	0.3939 (0.1557)	0.6094*** (0.2015)	0.6809*** (0.1060)	0.5746 (0.4056)	-0.3355 (0.2259)
Irrigated	-0.0202 (0.4951)	-0.1301 (0.1182)	0.1227 (0.1513)	0.2134*** (0.0829)	-0.4944 (0.3143)	-0.7591*** (0.1811)
Rainfed	0.0648 (0.4523)	-0.0346 (0.1057)	0.1795 (0.1380)	0.1368* (0.0718)	-0.5326** (0.2678)	-0.6856*** (0.1477)
Constant	2.5551***	0.4611**	0.4686**	-0.1366	1.0299**	1.3165
R^2	0.17	0.31	0.27	0.51	0.29	0.51
Adjusted R^2	0.14	0.29	0.25	0.49	0.26	0.49
F-test	5.30***	11.82***	13.57***	27.01***	9.62***	24.60***

1. For definitions of the variables see Table 5.15.
2. Figures in parentheses are standard errors.
No. of observations = 297
***, **, and * = 1, 5, and 10% probability levels, respectively.

Intensification of goat production increases significantly with increase in human population density as well as urbanization, while in the case of sheep, only urbanization has a positive effect. Further, intensification of both is significantly higher on smallholdings. The effect of rainfall on sheep intensification is negative and significant, while its effect on goat intensification is positive but insignificant. Nevertheless, intensification of goat production (but not that of sheep) significantly declines with increase in irrigation level. Similarly, common grazing land has a positive and significant effect on sheep intensification, but not on that of goat. The differential effect of certain variables on sheep and goat intensification need to be understood in the light of their biological characteristics and production conditions. Goats are adaptable to environments in all rainfall ranges, while sheep do not thrive in high rainfall areas and thus are largely concentrated in arid environments having considerable common grazing resources. Further, the grazing habits of the two are different; goats can graze on shrubs, herbs and grasses, while sheep graze mainly on grasses on the ground. The significant positive effect of common grazing lands on sheep intensification, and the significant negative effect of irrigation on goat intensification are due to differences in their grazing habits. These results suggest that livestock production systems evolve in response to a number of interactive forces.

On the whole, human population density, climate, technology and size of landholdings appear to be the major determinants of livestock intensification. The role of urbanization in the process of intensification is also significant with rising demand for animal foods and the declining importance of the non-food functions of livestock.

5.3.2. Adoption of Crossbreeding Technology

Adoption of crossbred cattle, sheep and improved poultry is influenced by agro-ecological and socio-economic factors and the level of technology adoption in the crop sector. The size of livestock holdings (herd size/poultry size) could be an important factor determining adoption of crossbreeding technology. Demand-side factors and infrastructure variables such as roads, markets, veterinary institutions, etc., are also more important, because outlets for milk or meat markets are a necessary precondition for the adoption of crossbreeding technology.

Crossbred Cattle: Adoption of crossbreeding technology is expected to be influenced by demand for livestock products. Two variables, i.e., population density and urbanization, are included in the models to examine the influence of demand. As expected, adoption of crossbred cattle is positively influenced by human population and urbanization. This is obvious, as indigenous cattle in densely populated regions cannot produce enough milk to satisfy local and urban demand. Feed availability is an important factor in the adoption of crossbred cattle, as these animals require more of it. The coefficient on feed is positive, indicating that adoption of crossbred cattle is subject to feed availability, particularly from forage crops and concentrates. Irrigation and rainfall also influence a farmer's decision to adopt crossbreds since the availability of water is important not only to produce feed and fodder but also for watering animals. The water requirement of crossbreds is generally high compared to indigenous breeds. Further, we have observed earlier that density of working cattle is low in irrigated systems, meaning there is low demand for low-producing indigenous breeds there. Both irrigation and rainfall have a positive and significant influence on the adoption of crossbred cattle. However, high variability in rainfall (coefficient of variation) discourages adoption of crossbred technology. Further, crossbred cattle require more initial investment and higher operational expenses, which may discourage the poor to adopt the technology. This is revealed by a negative and significant coefficient on smallholders (Table 5.17).

Table 5.17. Determinants of adoption of crossbred cattle and sheep, model results, India.

	Crossbred cattle		Crossbred sheep	
Variables	Estimated coefficient	t- statistic	Estimated coefficient	t-statistic
POPDEN	0.0151***	3.06	0.0046	1.47
URBPER	0.1089*	1.88	0.0168	0.45
MSFPER	-0.2436***	-3.66	-0.2122***	-5.67
FEED	2.3818***	2.59	-[1]	-
VETY	114.28***	10.96	43.8862***	6.72
ROAD	17.1212***	6.41	8.6416***	4.99
IRRI	0.0963**	2.15	0.1636***	6.75
RAIN	0.0055***	3.43	0.0054***	5.24
CVRAIN	-0.1183***	-2.73	0.0018	0.06
GRAZE	-	-	0.0229**	2.35
SHSIZE	-	-	-0.4323	-1.39
Constant	4.3222	0.47	-3.5162	-0.69
R^2	0.63		0.47	
Adjusted R^2	0.61		0.45	
F statistics	45.49		24.10	
No. of observations	280		280	

1. Explanatory variable not included in the model run.
***,** and * = Significant at 1, 5 and 10 % probability levels, respectively.

Markets, institutions and infrastructure facilitate adoption of technology by cutting down transaction costs in the acquisition of inputs and services. Two variables, i.e., roads and veterinary institutions, have been included in the set of explanatory variables. Both variables have a positive and significant effect on adoption. Veterinary institutions are more important as crossbreds are more prone to diseases and other health problems.

Crossbred Sheep: Adoption of crossbred sheep is negatively associated with the proportion of smallholders, perhaps due to a lack of knowledge among farmers and the high susceptibility of crossbreds to diseases. On the other hand, it has a positive association with availability of common land, which is important for sheep. Irrigation and rainfall positively influence adoption. Sheep are averse to high rainfall, and despite a low density of sheep in high-rainfall areas, adoption of crossbred sheep is high there. Roads and veterinary institutions are positively associated, indicating the importance of health services and accessibility to markets.

Crossbred Pig: Factors influencing adoption of crossbred pigs are similar to those for sheep. Crossbred pigs have a negative relationship with farm size and a positive relationship with rainfall, irrigation, roads and veterinary institutions (Table 5.18).

Table 5.18. Determinants of adoption of crossbred pig and improved poultry, model results, India.

	Crossbred pig		Improved poultry	
Variables	Estimated coefficient	t- statistic	Estimated coefficient	t-statistic
POPDEN	0.0047	1.12	0.0096	1.40
URBPER	0.0630	1.27	0.4213***	5.10
MSFPER	-0.2468***	-5.06	0.0207	0.26
VETY	88.9688***	10.20	142.606***	10.16
ROAD	6.7914***	2.92	10.5528***	2.78
IRRI	0.2239***	6.66	0.2012***	3.79
RAIN	0.0060***	4.60	-0.0066***	-3.11
PGSIZE	1.7260	0.75	-[1]	-
CVRAIN	-0.0858**	-2.22	0.0924	1.44
PLSIZE	-	-	1.2234	4.69
Constant	6.9372	1.01	-19.9492*	-1.81
R^2	0.53		0.55	
Adjusted R^2	0.51		0.54	
F statistics	33.39		36.75	
No. of observations	280		280	

1. Explanatory variable not included in the model run.
***,** and * = Significant at 1, 5 and 10% probability levels, respectively.

Improved Poultry: Urbanization is an important driving force behind adoption of improved poultry. Income growth and changes in tastes and preferences are causing rapid changes in the food basket in favor of animal products. It may be recalled that demand for poultry meat and eggs in India has grown faster than any other animal product. Veterinary institutions and roads carry positive and significant signs, emphasizing the role of animal heath services and market access in the adoption of improved technologies. Irrigation has a positive influence, while rainfall has a negative influence on the adoption of improved poultry. Poultry size is positive and significant, implying that adoption is higher when poultry size is large, meaning adoption would be low, particularly where poultry is a backyard activity.

5.3.3. Productivity

Productivity in Crop-Livestock Systems depends on agro-ecological factors such as rainfall, irrigation, moisture availability index, length of growing period, etc.; adoption of improved technologies; socio-economic factors such as landholding size, population density, etc., and infrastructure variables. The interaction between crop and livestock sectors is captured through the variable feed availability in the livestock productivity equation and livestock numbers in the crop productivity equation. Definitions and measurements of the variables are given in Table 5.15.

Crop productivity: Irrigation, rainfall, market and road density positively influence crop productivity. Variables such as adoption of high-yielding varieties, mechanization and fertilizer use were excluded because of their high correlation with irrigation (Table 5.19). Markets and roads influence productivity by providing access to input and output markets enabling commercialization of production i.e., adoption of improved cultivars and package of practices. Crop productivity declines with farm size. This confirms earlier evidence of a negative relationship between farm size and productivity (Berry and Cline 1979 and Bhalla 1979). Livestock density is positively and significantly associated with crop productivity. The higher the livestock density, the greater is the level of interaction between the two production systems and the greater are the positive environmental contributions of the sector (Mishra 2002). Crop productivity, however, is negatively associated with work animals. This is due to the fact that work animals cannot ensure timeliness of agricultural operations like sowing, especially in rainfed areas. There is perhaps an optimum livestock density beyond which crop productivity could be affected adversely, but that has not been estimated here. Better irrigation, rainfall, markets and roads all lead to an increase in crop productivity.

Table 5.19. Determinants of crop productivity, model results, India.

Variables	Estimated Elasticities	t- statistic
IRRI	0.3484***	10.02
RAIN	0.3139***	4.29
WORKAN	-0.0752**	-2.00
MARKET	0.1312***	4.79
ROAD	0.1080***	3.97
FSIZE	-0.1502***	-3.57
LUDEN	0.1888***	2.57
Constant	4.8290***	9.00
R^2	0.66	
Adjusted R^2	0.65	
F statistics	68.40	
No. of observations	259	

***,** and * = Significant at 1, 5 and 10% probability levels, respectively.

Livestock productivity: Livestock productivity is negatively related with work animal density. This is because in districts with high work animal density, the focus is on the dual uses of cattle, i.e., for work and milk. In the process, cows are reared for producing male calves while milk production is secondary.

Feed availability has a significant influence on livestock productivity. Thus, livestock productivity is closely linked with the productivity of the crop sector, particularly for by-products from food, feed and forage crops (Table 5.20).

Table 5.20. Determinants of livestock productivity, model results, India.

	Livestock		Cattle		Buffalo	
Variables	Estimated elasticities	t- statistic	Estimated elasticities	t- statistic	Estimated elasticities	t- statistic
WORKAN	-0.1384***	-4.87	-0.2054**	-8.77	-	-
ROAD	0.0150	0.36	0.0410	1.07	0.0484	1.04
FEED	0.2944***	5.37	0.1595***	3.07	0.3463***	5.97
VETY	0.2102***	4.83	0.1107***	2.74	0.2603***	4.88
CBCATL	0.0640***	4.12	0.0880***	5.75	-	-
CBSHEP	0.0000	0.44	-	-	-	-
LSHOLD	-0.0588	-1.34	0.0103	0.24	-0.0768	-1.48
Constant	6.7893***	48.75	6.1723***	41.89	7.4597***	39.76
R^2	0.53		0.53		0.32	
Adjusted R^2	0.52		0.52		0.31	
F statistics	41.13		48.23		30.28	
No. of observations	259		259		259	

***,** and * = Significant at 1, 5 and 10% probability levels, respectively.

Veterinary institutions have a positive and significant influence on livestock productivity. Livestock productivity is also positively associated with adoption of crossbred cattle. Livestock holding size is negative but not significant.

5.4. Livestock, Poverty and the Environment

There is a positive relation between poverty and livestock density, implying the importance of livestock in the livelihoods of the poor (Figure 5.1). However, livestock productivity is generally low where incidence of rural poverty is high (Figure 5.2). This is so because livestock not only serves as an income source for the poor but also fulfills several other functions that cannot be assigned a monetary value. Although indigenous livestock breeds may not be able to compete with improved breeds in terms of milk and meat production, they continue to represent the lifeline of rural populations. They fulfill a much wider range of functions and provide a larger range of products. For instance, indigenous breeds perform several useful functions -- output functions, input functions, the assets and security function and the social and cultural function (Anderson et al. 2002). Their advantages, among others, include low production cost, better adaptability to local conditions, moderate feed demands, hardiness, disease resistance, greater longevity, low-input demand, local adaptability to vegetation cover and high genetic variability.

Much of empirical literature emphasizes livestock as a source of income (Anderson et al. 2002), neglecting their uses, adaptation to different feed resources and environments and other functions. The exploitation of the inherent possibilities of this variation has so far been neglected in favor of the importation into developing countries of so-called upgraded animals (Orskov 1993). Households have a dual economic nature in that they are both a family and an enterprise. They make decisions based on both production and consumption goals, which distinguishes them from other farm enterprises (Ellis 1988).

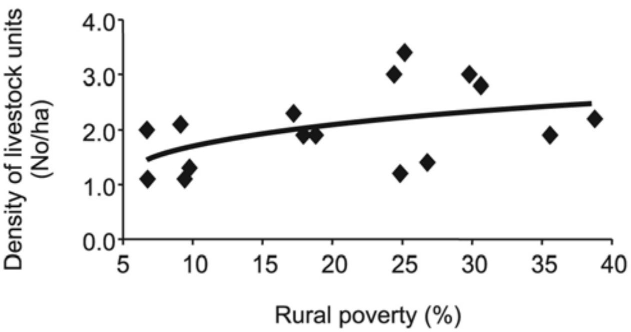


Figure 5.1. Relationship between density of livestock units and rural poverty in India, 1998 (system level).

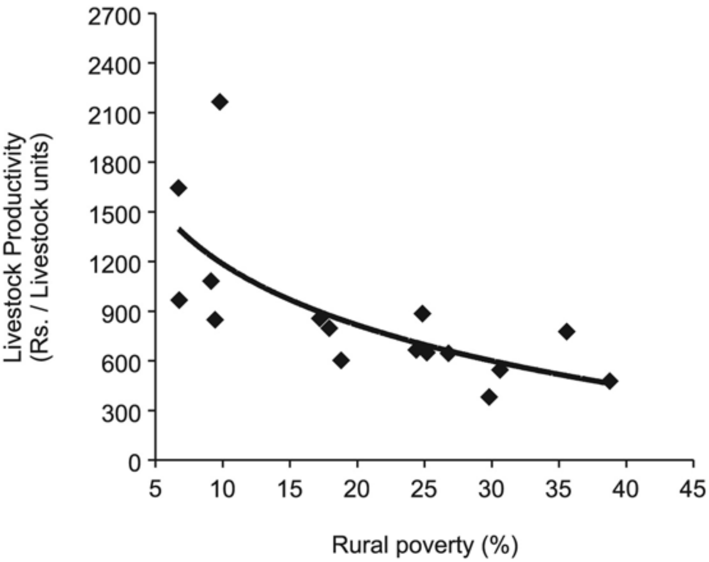


Figure 5.2. Relationship between livestock productivity and rural poverty in India, 1998 (system level).

Small ruminants are mainly raised by resource-poor households in marginal environments with acute shortage of feed and fodder resources. The system of production is mainly extensive and most of the feed and fodder requirements are met from grazing on common lands. This results in low productivity. Small ruminants are the single largest source of income for the landless and small farmers, ranging between 20 and 70% of their total income(Birthal et al. 2003). Thus, improvements in the productivity of small ruminants would benefit the poor, besides others.

As already noted, feed availability significantly influences livestock productivity (Figure 5.3) besides other factors. Thus, enhancing the contribution of livestock through productivity-enhancing nutrition while meeting the multiple needs of livestock keepers will contribute to poverty reduction.

The relationship between rural poverty and crop productivity, though negative, is not significant (Figure 5.4). Crop productivity is high in better-endowed regions with high irrigation and rainfall. Change in cropping pattern towards oilseeds, fruits and vegetables, and other commercial crops have contributed to increasing crop productivity, but have adversely affected livestock productivity in some instances.

The influence of livestock on crop productivity is less clear. In large parts of the country, the use of fertilizers has reduced the use of animal dung (manure) as plant nutrient. Although the use of manure in absolute terms has increased, its share in total plant nutrients has declined from 43% in the early seventies to 13% in 1998. The sustainability of major cropping systems based on rice and wheat in the Indo-Gangetic Plains (IGP) of India are now under threat because of a decline in organic matter content in the soil and the depletion of groundwater resources[10] (Kumar et al. 1999 and Pingali and Shah 1999).

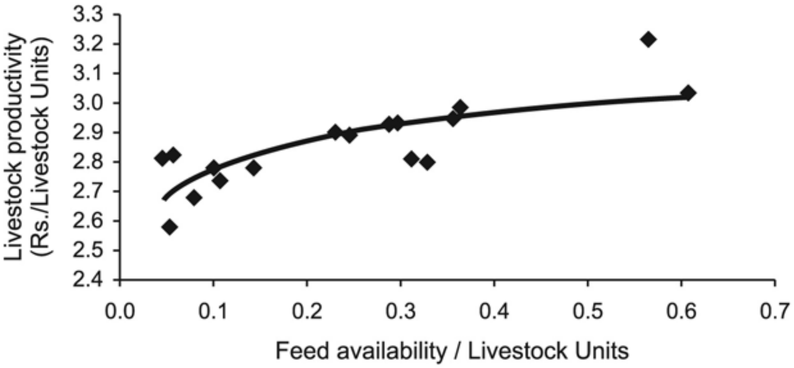


Figure 5.3. Relationship between livestock productivity and feed availability in India, 1998 (system level).

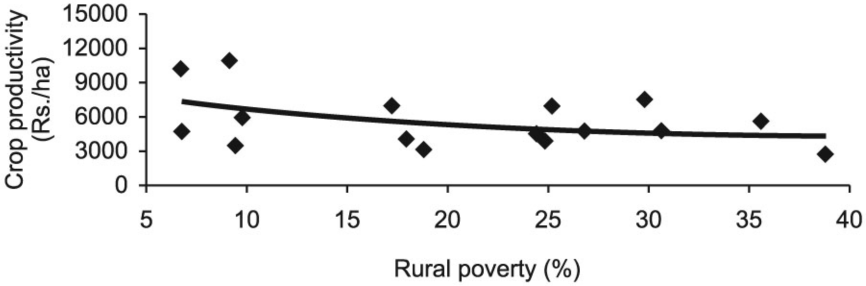
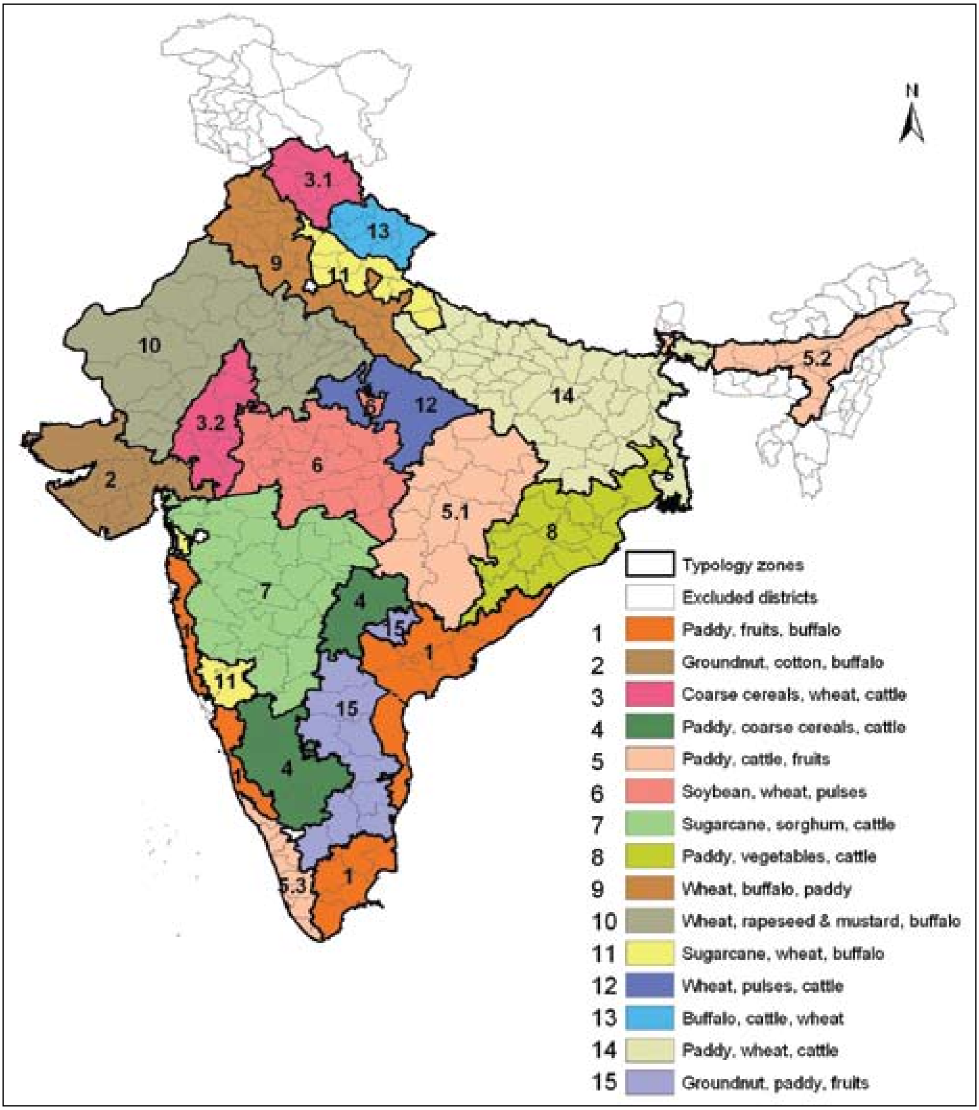
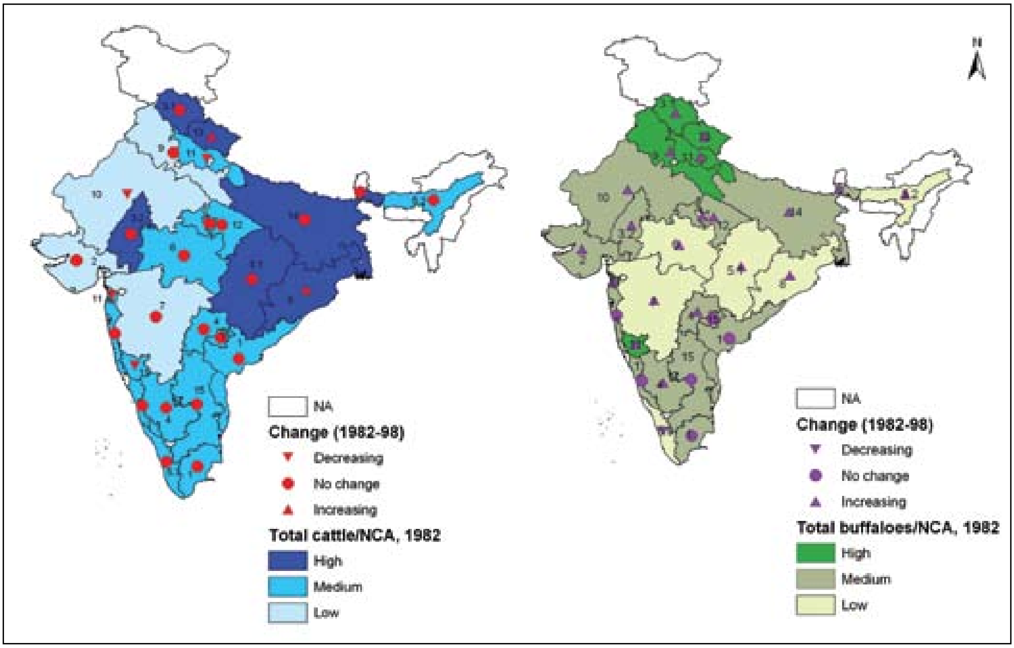


Figure 5.4. Relationship between crop productivity and rural poverty in India, 1998 (system level).

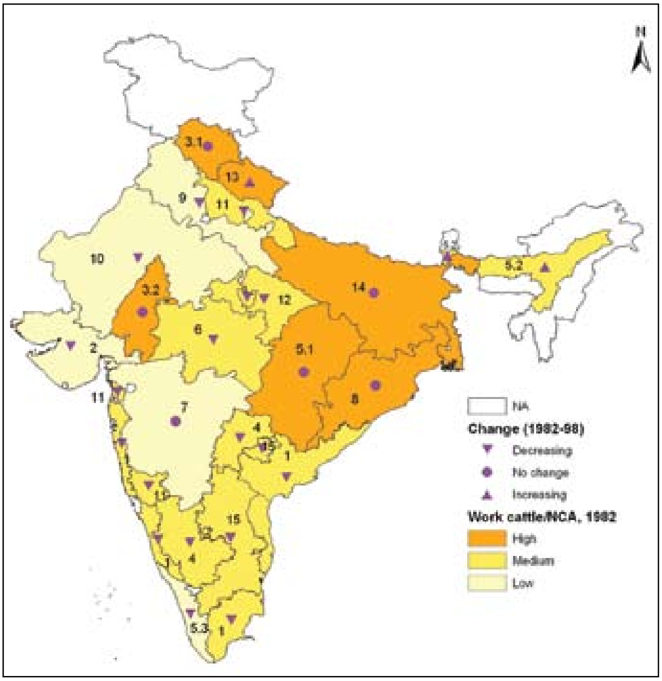
[10] Deteriorating crop-livestock interaction has major implications for the sustainability of both crop and livestock sectors, and has received no attention so far. Progressive replacement of draft animals by electrical and mechanical sources of power, diminishing reliance on crop residues as ruminant fodder, large-scale burning of straws and progressive decline in recycling of farmyard manure for enriching soils have all upset the traditional symbiotic interactions between crops and livestock in the smallholder, mixed farming systems in the IGP.



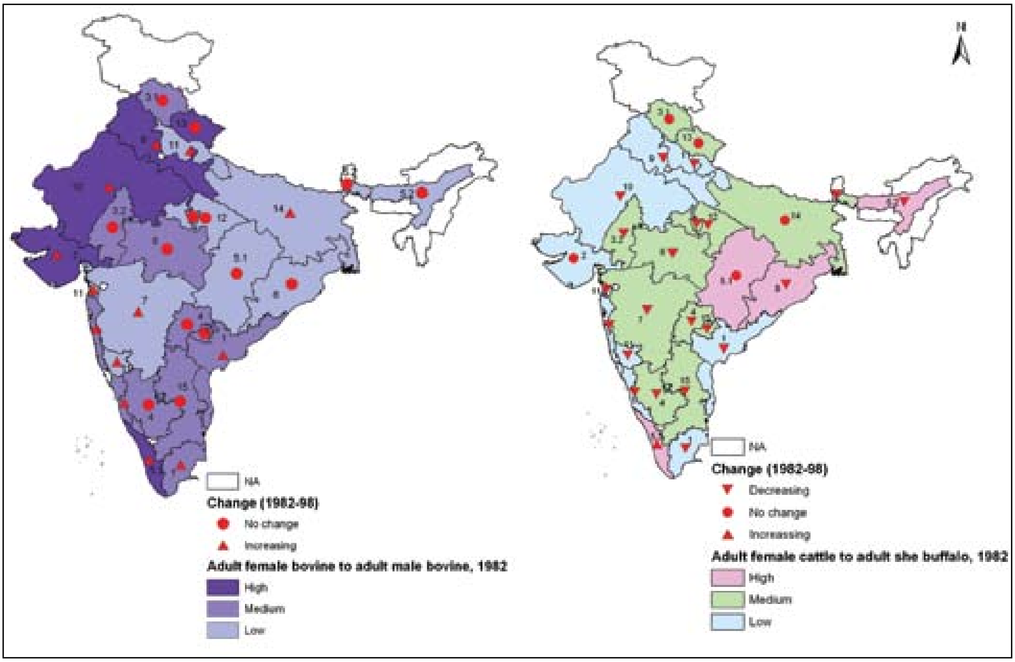
Map 5.1. Crop-Livestock Systems in India, 1998.



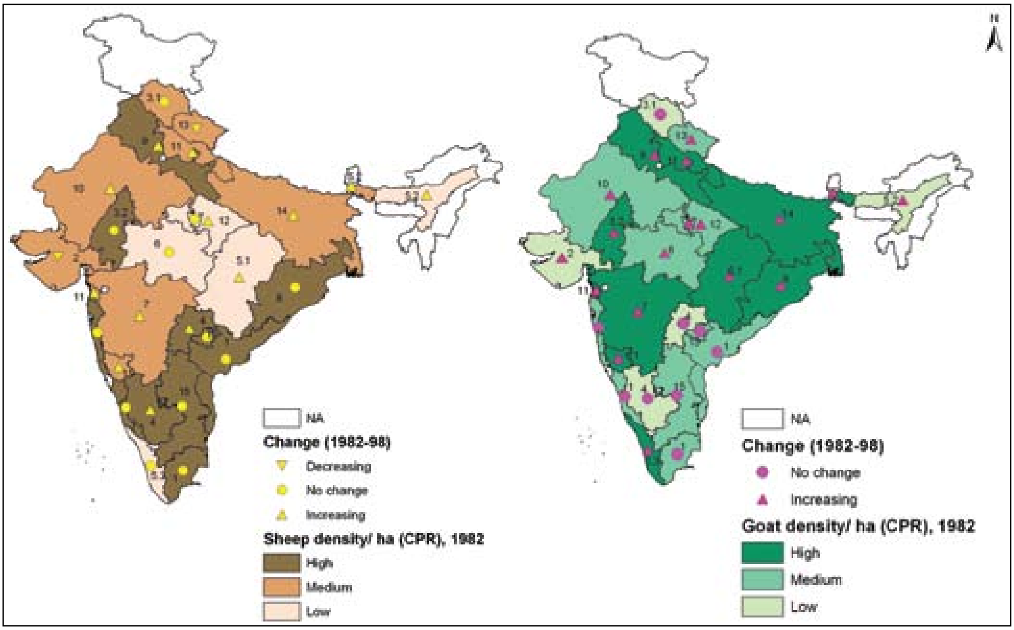
Map 5.2. Density of cattle and buffaloes and change in India, 1982–1998.



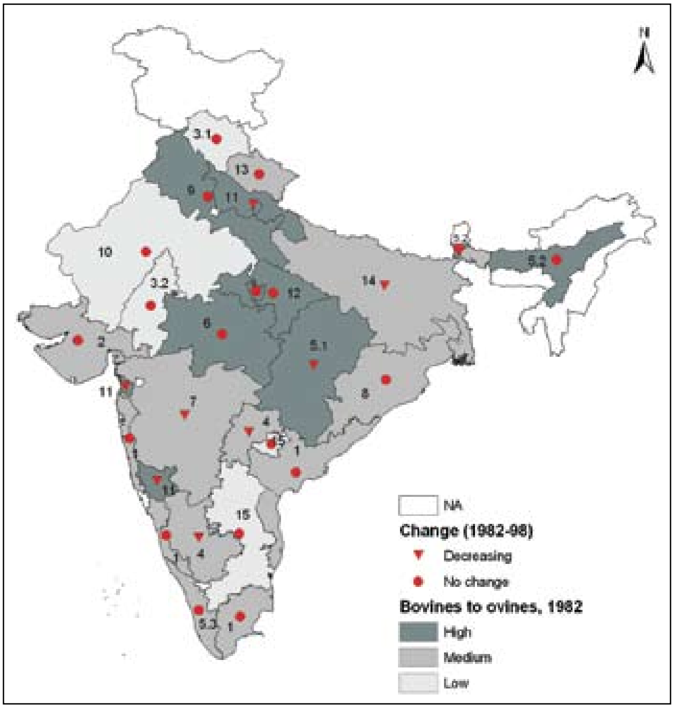
Map 5.3. Density of work cattle and change in India, 1982–1998.



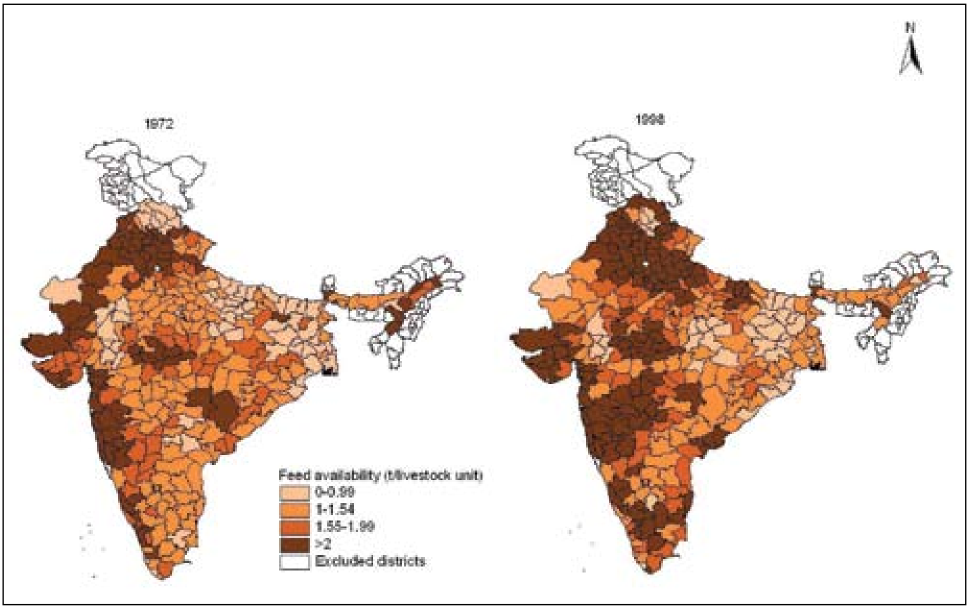
Map 5.4. Bovine composition and change in India, 1982–1998.



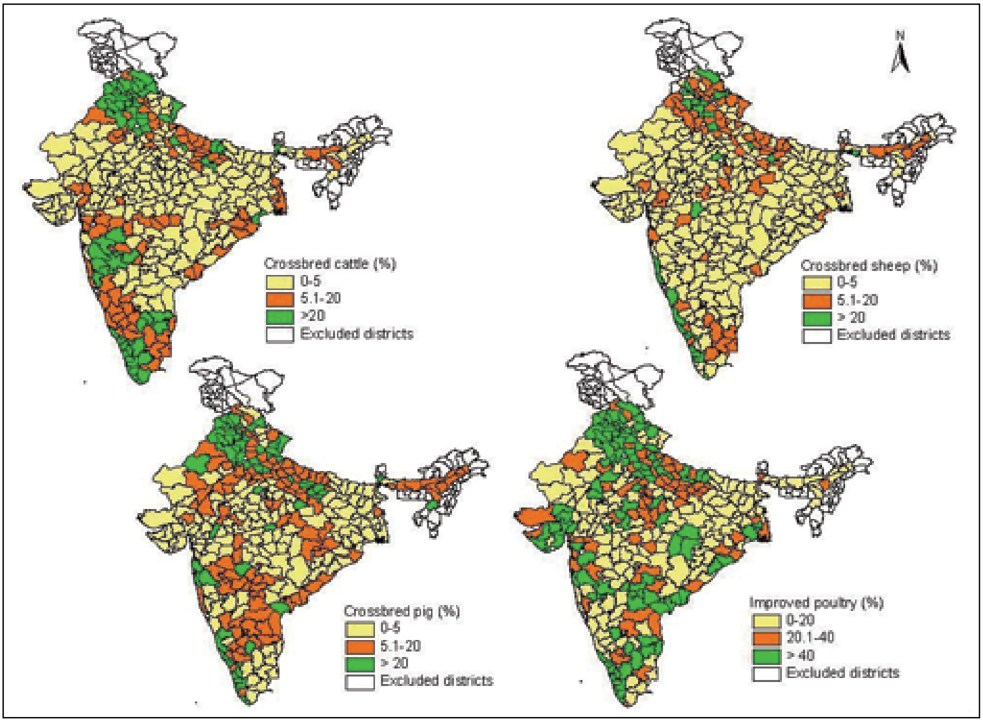
Map 5.5. Sheep and goat density to grazing land (CPRs) and change in India, 1982–1998.



Map 5.6. Ratio of bovines to ovines and change in India, 1982–1998.



Map 5.7. District-level feed (crop residues, grasses, fodder and concentrates) availability in India on dry matter basis, 1972 and 1998.



Map 5.8. District-level adoption of crossbred cattle, sheep and pig and improved poultry in India, 1998.

Appendix 5.1. State and districts in India by Crop-Livestock Systems (CLSs).

CLS	State	Districts[1]
3.1	Himachal Pradesh	Bilaspur, Chamba, Kangra, Kinnaur, Kulu, Lahaul & Spiti, Mandi, Simla, Sirmaur and Mahasu/Solan
5.1	Madhya Pradesh	Balaghat, Bastar, Bilaspur, Durg, Mandla, Raigarh, Raipur, Surguja, Shahdol and Sidhi
	Maharashtra	Bhandara and Chandrapur
5.2	West Bengal	Darjeeling
	Assam	Dibrugarh, Darrang, Goalpara, Kamrup, Karbi-Anglong, N.C.Hills, Lakhimpur, Nowgong, Sibsagar and Cachar
5.3	Tamil Nadu	Kanyakumari
	Kerala	Alleppey, Cannanore, Ernakulam, Kottayam, Kozhikode, Malappuram, Palghat, Kollam, Thrissur and Thiruvananthapuram
8	Orissa	Bolangir, Balasore, Cuttack, Dhenkanal, Ganjam, Kalahandi, Keonjhar, Koraput, Mayurbhanj, Phulbani, Puri, Sambalpur and Sundergarh
	West Bengal	Burdwan, Hooghly and Midnapore
13	Uttar Pradesh	Almorah, Chamoli, Dehradun, Garhwal, Pithorgarh, Tehri Garhwal and Uttar Kashi
6	Madhya Pradesh	Betul, Chhindwara, Damoh, Dewas, Dhar, East Nimar (Khandwa), Guna, Hoshangabad, Indore, Mandsaur, Narsinghpur, Raisen, Rajgarh, Ratlam, Sagar, Sehore, Seoni, Shajapur, Tikamgarh, Ujjain and Vidisha
	Maharashtra	Nagpur
	Rajasthan	Jhalawar
12	Madhya Pradesh	Chhatarpur, Datia, Jabalpur, Panna, Rewa, Satna and Shivpuri
	Uttar Pradesh	Banda, Hamirpur, Jalaun and Jhansi
11	Maharashtra	Kolhapur
	Uttar Pradesh	Bareilly, Bijnore, Kheri, Meerut, Moradabad, Muzaffarnagar, Nainital, Saharanpur, Sitapur and Pilibhit
	Gujarat	Bulsar
	Haryana	Ambala
	Karnataka	Belgaum
14	West Bengal	Bankura, Birbhum, Howrah, Jalpaiguri, Cooch-Behar, Malda, Murshidabad, Purulia, 24-Paragana, West Dinajpur and Nadia
	Bihar	Bhagalpur, Darbhanga, Dhanbad, Gaya, Hazaribagh, Monghyr, Muzzafarpur, Palamau, Champaran, Patna, Purnea, Ranchi, Shahabad, Saharsa, Singhbhum, Santhal Paragana and Saran
	Uttar Pradesh	Allahabad, Azamgarh, Bahraich, Barabanki, Basti, Deoria, Faizabad, Fatehpur, Ghazipur, Gonda, Ballia, Gorakhpur, Hardoi, Jaunpur, Lucknow, Mirzapur, Pratapgarh, Rae Bareily, Unnao, Varanasi and Sultanpur

Continued...

Appendix 5.1. *Continued...*

1	Maharashtra	Ratnagiri, Raigad/Kolaba and Thane
	Tamil Nadu	Chengalpattu, Madurai, Ramanathapuram, Thanjavur, Tiruchirapalli and Tirunelveli Kattaboman
	Andhra Pradesh	East Godavari, Guntur, Khammam, Krishna, Nalgonda, Nellore, Srikakulam, Visakhapatnam and West Godavari
	Karnataka	Dakshina Kannara, Kodagu (Coorg), and Uttara Kannara
2	Gujarat	Ahmedabad, Amreli, Bhavnagar, Jamnagar, Junagadh, Kutch, Kaira, Rajkot, Surendranagar and Barod
3.2	Madhya Pradesh	Jhabua
	Rajasthan	Ajmer, Banswara, Bhilwara, Chittorgarh, Dungarpur and Udaipur
	Gujarat	Panchmahals and Sabarkantha
4	Andhra Pradesh	Adilabad, Hyderabad, Karimnagar, Medak and Nizamabad
	Karnataka	Bangalore, Bellary, Chickmagalur, Chitradurga, Dharwad, Hassan, Kolar, Mandya, Mysore, Shimoga and Tumkur
7	Madhya Pradesh	West Nimar (Khargone)
	Maharashtra	Ahmednagar, Akola, Amravati, Aurangabad, Beed, Buldhana, Dhulia, Jalgaon, Nanded, Nasik, Osmanabad, Parbhani, Pune, Sangli, Satara, Solapur, Wardha,Yeotmal
	Gujarat	Broach and Surat
	Karnataka	Bidar, Bijapur, Gulbarga and Raichur
10	Madhya Pradesh	Bhind, Gwalior and Morena
	Rajasthan	Alwar, Barmer, Bharatpur, Bikaner, Bundi, Churu, Ganganagar, Jaipur, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Kota, Nagaur, Pali, Sawai Madhopur, Sikar, Tonk and Sirohi
	Uttar Pradesh	Agra and Mathura
	Gujarat	Banaskantha and Mehsana
	Haryana	Mahendragarh
15	Tamil Nadu	Coimbatore, North Arcot, Salem and South Arcot
	Andhra Pradesh	Anantapur, Chittoor, Cuddapah, Kurnool, Mahabubnagar and Warangal
9	Punjab	Amritsar, Bhatinda, Gurdaspur, Ferozepur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Patiala, Roopnagar and Sangrur
	Uttar Pradesh	Aligarh, Budaun, Bulandshahar, Etah, Etawah, Farrukhabad, Kanpur, Mainpuri, Rampur and Shahjahanpur
	Haryana	Gurgoan, Hissar, Jind, Karnal and Rohtak

1. Districts correspond to 1970 district boundaries, i.e., districts formed after 1970 have been merged with their parent districts.

Appendix 5.2. Conversion factors[1] for estimating feed and fodder availability.

Grain: Straw.

Slender straw: Wheat – 1.3, rice – 1.4 and barley – 1.3.

Coarse straw: Maize – 2.00, sorghum – 3.00, pearl millet – 2.00, finger millet – 2.00 and other minor millets – 2.00.

Leguminous straw: Chickpea – 2.00, pigeonpea – 2.5, minor pulses – 2.00, sugarcane tops – 0.25, groundnut – 1.00, sesame – 1.00, rape and mustard – 0.5 and soybean – 0.5.

After conversion into straw, utilization was estimated for paddy and wheat straw. In all states except Uttar Pradesh, Punjab and Haryana, utilization of paddy straw was 85% of the converted total. For Punjab and Haryana, paddy straw utilization was zero, and for Uttar Pradesh utilization was taken as 60% of straw production. In the case of wheat, utilization was 90% in all states except Punjab and Haryana, where it was 75%.

Agro-industrial By-products (AIBPs)

Grains: Rice – 5%, wheat – 5%, sorghum – 5%, pearl millet – 5%, maize – 5% and finger millet – 5%.

By-products: Chickpea – 15%, pigeonpea – 15%, minor pulses – 15%, rice – 5%, wheat – 10%, groundnut – 0.7 × 0.55, sesame – 0.6, rape and mustard – 0.65, safflower – 0.7, sunflower – 0.7, castor – 0.65, linseed – 0.65, cottonseed – 2 × 0.8 and soybean – 0.73.

Grasses from grazing land

Public lands: Forests – 40%, permanent pastures (PP) – 80% and culturable waste (CW) – 80%.

Private lands: Rice bunds – 5% of rice area and fallows – 90%.

Total grazing land = 40% forests + 80% PP + 80% CW + 5% rice area + 90% current fallow + 90% other fallow. Production of grasses from grazing lands are calculated using the following formula: [(annual rain × 4) – 800] / 1000t DM / hectare.

From grazing lands, 50% of total DM production is assumed to be utilized for all states except Assam, Bihar, Himachal Pradesh and Orissa, where it is 40%.

Forage crops

Data are available only for area under forage crops. Production was taken to be as follows: 50 t per hectare – irrigated land; and 25 t per hectare – unirrigated land.

Irrigated land determined on the basis of: Fodder crop area under irrigation/fodder crop area × 100 = fodder crop irrigated area. Where irrigated area under fodder crops is more than 50%, production was estimated using yield conversion for irrigated land.

Conversion into dry matter

Fodder crops – 25% of total, crop residues – 90% of total, concentrates – 90% of total and sugarcane tops – 25% of total.

1. For details, see Ranjhan (1991, 1993).

Continued...

Appendix 5.2. ***Continued...***

Standard Livestock Units[2]

Adult male cattle: 1.20
Adult female cattle: 1.00
Adult female cattle crossbred: 1.20
Cattle young stock: 0.50
Adult male buffalo: 1.20
Adult female buffalo: 1.20
Buffalo young stock: 0.50
Goat: 0.10
Sheep: 0.10
Poultry – 100 adult poultry = 0.005.

2. See Mishra and Sharma (1990).

Chapter 6

Typology of Mixed Crop-Livestock Systems in Sri Lanka

As elsewhere in South Asia, mixed farming system is the dominant form of agricultural production in Sri Lanka, with livestock being an integral component. Livestock are a source of food, draft power and manure, supplementing the livelihoods of about 35% of the farming population associated with livestock (Kodituawakku 1999).

The share of livestock in Sri Lanka's agricultural gross domestic product increased from 11 to 14% between 1980–82 and 2000–02, while the share of the agricultural sector in the GDP fell from 28 to 16%. Livestock production in Sri Lanka, particularly diary, is however under stress. Milk production has almost stagnated. The country depends on imports to meet the rapidly growing domestic demand. Productivity of meat animals, especially pigs and goats, is higher in Sri Lanka than in any other country in the region, but has hardly shown any improvement over the last two decades.

6.1. Crop-Livestock Systems Typology

There is considerable variation in Sri Lanka's topography and agro-climatic conditions. Based on this, the country has been divided into three agro-climatic zones i.e., the wet, dry and intermediate zones. These zones are further sub-divided, based on elevation and land use, into hill/up country, mid country, low country wet zone, low country dry zone, coconut triangle and Jaffna peninsula. Land use is dependent on rainfall and elevation.

Dividing the country into Crop-Livestock Systems with the district serving as a unit may not be ideal as many of these administrative units cut across agro-climatic zones and show considerable intra-district variations in topography, elevation, rainfall and land use. Despite this limitation, a typology of mixed Crop-Livestock Systems has been constructed using the methodology described in Chapter 4.

By clustering crop and livestock activities, we obtained six CLSs in Sri Lanka (Map 6.1 and Table 6.1). Incidentally, there is a close correspondence between these systems and the agro-ecological classification. Paddy is a dominant activity in CLSs 1 and 2[11], plantation in systems 3, 4 and 5 and vegetables and fruits in system 6. Fruits and/ or vegetables comprise the second most important activity in most CLSs. Amongst

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[11] Coconut is the dominant crop in this zone. However, we did not include coconut in our classification; hence paddy emerged as the dominant activity in this system.

different livestock species, large ruminants are important in all CLSs, but along with these, goat rearing is also practiced in a significant way in CLSs 1, 2 and 4.

Table 6.1. Agricultural activity-based systems in a crop-livestock typology, Sri Lanka, 1998.

System	No. of districts	Location (province)	Agro-ecological zone	Major crop[1] and livestock[2] activities
1	9	Southern province (1)[3], Northern province (4), North central province (2) and Eastern province (2)	Dry zone (South) (1) [3], Dry zone (North) (4), Dry zone (Central) (2) and Dry zone (East) (2)	Paddy (83), vegetables and fruits (6), cattle, buffalo and ovine
2	3	Western province (1) and North western province (2)	Wet low country and coconut triangle (3)	Paddy (44), vegetables and fruits (33), cattle, buffalo, ovine and coconut[4]
3	5	Western province (2), Southern province (2) and Sabaragamuwa province (1)	Wet low country (5)	Plantation (48), paddy (28), vegetables and fruits (11) and cattle
4	3	Uva province (1), Sabaragamuwa province (1) and Central province (1)	Up country (3)	Plantation (60), vegetables and fruits (18), paddy (9), cattle and ovine
5	2	Central province (2)	Mid country (2)	Plantation (36), vegetables and fruits (29), spices (20), cattle and buffalo
6	2	Uva province (1) and Eastern province (1)	Dry low country (2)	Vegetables and fruits (39), paddy (27), minor cereals (11), cattle and buffalo

1. Percentage of GCA.
2. Based on livestock density.
3. Figures in parentheses are the number of districts.
4. Coconut growing is a dominant activity in this zone. However its area was not included in clustering districts.

6.2. Characteristics of Crop-Livestock Systems

6.2.1. Geographical Dispersion

There is a geographical contiguity in the districts within all CLSs. CLS 1 extends from the north of Sri Lanka to the south, and is the largest system spread over 9 districts largely falling in the low country dry zone. It covers 42% of the total geographical area, and shares 38% of the grazing land and 36% of net cropped area.

CLS 1 accounts for 21% of the country's population, with a density of 144 persons/sq. km (Table 6.2). Normal rainfall is 1522 mm, lower than in any other CLS.

Table 6.2. Relative importance of selected indicators in Crop-Livestock Systems in Sri Lanka, 1998.

System	Geographical area (1988)	Grazing land (1988)	NCA (incl tea+rubber)	NCA (excl tea+Rubber)	Total population	Pop density (no./sq. km)	Urban pop (% of total)
1	42.0	38.2	36.3	48.4	21.1	144	19.4
2	14.1	5.0	11.0	13.8	20.4	413	15.9
3	10.6	2.3	22.9	14.7	31.3	848	37.1
4	12.0	23.0	15.6	7.3	12.6	300	7.6
5	6.0	12.7	7.9	7.5	9.7	462	12.5
6	15.3	18.8	6.3	8.2	5.0	93	8.9
All systems[1]	**6,561**	**91**	**1,390**	**1,042**	**18,774**	**286**	**21.5**

1. Geographical area, grazing land, NCA in '000 ha and population in '000.

CLS 6 also falls under the low country dry zone. It accounts for 15% of the geographical area, 6% of the cropped area and 5% of the population. The population density is one of the lowest in this system (93 persons/sq. km). Together, systems 1 and 6 account for most of the geographical area but have a lower share in population and cropped area.

CLSs 2 and 3 cut across the agro-ecological classification and fall in the wet low country and coconut triangle zones. CLS 2 shares 14% of the country's geographical area and supports 20% of the population. CLS 3 also has a similar share in area and population. Population density is very high, about 850 persons/sq. km. Together, CLSs 2 and 3 cover a quarter of the geographical area housing more than half the total population of Sri Lanka and their share in cropped area is 11 and 23%, respectively.

CLSs 4 and 5 are found in the up, and mid country zone situated at an elevation of more than 450 m. CLS 4 occupies 16% of the net cropped area and has the highest rainfall (2522 mm/annum). The share of CLS 5 in net cropped area is relatively small.

6.2.2. Crop and Livestock Production

Paddy is the main crop occupying 0.84 million ha in Sri Lanka. Coconut plantations and fruits and vegetables are other important crops in the cropping pattern. CLSs 1 and 6 are the major food-producing systems with a share of 75% in the total area under paddy, 72% under minor cereals, 71% under pulses and 31% under fruits and vegetables. Under irrigated conditions, paddy is grown twice in both the rainy seasons, i.e., *maha* (northeast monsoon period) and *yala* (southwest monsoon period), while under rainfed conditions its cultivation is restricted to the *maha* season. Cash crops such as chillies and vegetables are also cultivated.

Spices and plantation crops are important in CLSs 3, 4 and 5. Fruits and vegetables are widely grown in these systems while cereals, pulses and oilseeds are grown over a very small area. Coconut is predominant in CLS 2 and accounts for 60% of the area under the crop in the country (Table 6.3). CLS 2 has a diversified cropping pattern -- about one-fourth of its area is under fruits and vegetables, 18% under pulses, 15% under oilseeds and 10% under paddy.

Table 6.3. Relative importance of crop activities, Sri Lanka, 1998.

System	Paddy	Other cereals	Pulses	Oilseeds	Vegetables and fruits	Spices	Plantation	Coconut
	% to all systems							
1	71.7	38.9	52.0	55.1	16.2	3.8	0.2	12.7
2	10.2	5.6	18.2	15.0	24.5	6.6	3.1	59.6
3	11.5	0.0	0.1	3.5	15.1	44.5	45.7	16.3
4	2.5	17.1	6.7	7.4	16.5	10.1	38.8	4.3
5	0.8	6.2	2.2	6.4	12.8	34.4	11.4	4.8
6	3.3	32.2	20.8	12.6	14.8	0.5	0.8	2.3
All systems[1]	**846**	**36**	**42**	**45**	**266**	**67**	**370**	**444**

1. Area under crops in ‘000 ha.

In 1998, Sri Lanka had 1.57 million cattle, 0.73 million buffaloes, 0.5 million goats and 9.5 million poultry birds. CLSs 1 and 6 have about half of the bovine, both cattle and buffalo, and 44% goats, but only a small proportion of non-ruminants (Table 6.4). Most cattle and buffaloes in these systems are of the indigenous type. Animals are generally left to graze in harvested paddy fields, and are moved to scrub land in the cultivation season.

The bulk of non-ruminant population is concentrated in CLSs 2 and 3. These systems contribute 45% of the total meat production. This large concentration is due to the large demand for non-ruminant meat, especially from the large urban population. These systems also have a sizeable share in other species. Dairy animals are generally grazed and/or tethered in harvested paddy fields or coconut plantations. Peri-urban dairying, based on crossbred cows and buffaloes, is also important in these systems. CLS 4 accounts for one-tenth of the cattle population but 21% of the milk production due to the high adoption of exotic breeds and their crosses.

Table 6.4. Relative importance of livestock activities, Sri Lanka, 1998.

System	Cattle	Buffalo	Goat	Sheep	Poultry	Pig	Total LU	Milk	Meat	Dairy co-operatives	Dairy centers
	% of total										
1	42.6	42.5	40.3	67.0	16.7	13.5	42.2	39.1	26.6	34.4	10.0
2	21.5	26.4	24.6	30.4	40.9	62.1	23.6	13.3	29.8	25.2	10.0
3	9.5	11.6	10.4	0.0	23.3	16.6	10.0	10.7	14.2	5.6	40.0
4	10.4	4.1	12.8	2.6	6.1	4.5	8.4	20.9	8.4	11.1	30.0
5	6.4	6.5	8.4	0.0	9.2	3.0	6.5	8.0	11.8	13.3	10.0
6	9.6	8.8	3.4	0.0	3.9	0.3	9.3	8.1	9.1	10.4	0.0
All systems[1]	**1,579**	**733**	**519**	**12**	**9,566**	**76**	**3,851**	**284**	**14**	**270**	**10**

1.Livestock population in '000 nos; milk in '000 mt; meat in '000 tons and dairy co-operatives and dairy centers in numbers.

6.2.3. Growth in Crop Area and Livestock Population

Between 1980 and 1998, the area under field crops declined in all CLSs except paddy in CLS 1. Paddy's share in GCA increased from 72 to 83%, indicating an increasing tendency towards monocropping (Map 6.2; Table 6.5 and Appendix 6.1). But overall, the area under paddy remained stagnant. Production of pulses, oilseeds and coarse grains is becoming less attractive despite a huge gap between domestic production and demand which is met through cheaper imports. On the other hand, the area under fruits and vegetables increased dramatically everywhere, registering an overall growth of over 2% per annum. In CLS 6, the share of fruits and vegetables nearly tripled between 1981 and 1998 (Map 6.3). The area under spices also increased in all CLSs but in most CLSs from a low base. The increase in area under fruits and vegetables, and spices was due to a growing export market. In 2002, fruits and vegetables worth Rs. 1000 million were exported (Wickramasinghe et al. 2003). Attractive export market prices coupled with government incentives for expansion led to higher growth in spice area (Herath 2002). The plantation area in the plantation-dominated CLSs 3, 4 and 5, however, declined marginally, mainly because of a decline in the profitability of rubber cultivation. These trends imply (i) a movement towards greater specialization in paddy at the cost of minor crops; and (ii) increasing diversification away from foodgrains towards fruits and vegetables, driven by income growth, urbanization and exports.

Table 6.5. Growth in area (% per annum) of selected crop groups, Sri Lanka, 1980–98.

System	Paddy	Other cereals	Pulses	Oilseeds	Root crops	Vegetables and fruits	Spices	Plantation	Coconut
1	3.18	0.88	0.41	-2.81	-1.50	1.09	1.85	5.57	0.70
2	-2.93	-3.54	-4.60	-5.13	-3.37	3.52	7.49	1.80	-0.02
3	-2.03	-16.90	-26.05	-3.30	-3.87	1.95	2.02	-1.18	0.10
4	-5.23	-3.18	-2.98	-3.06	-1.70	1.19	3.49	-0.39	1.70
5	-10.71	-6.51	-2.90	-5.21	-2.90	0.77	4.72	-4.84	1.02
6	-5.58	1.74	3.06	-2.78	-2.27	3.94	7.96	14.32	1.37
All systems	**0.10**	**-1.04**	**-1.80**	**-3.44**	**-2.55**	**2.07**	**3.24**	**-1.40**	**0.23**

The population of adult female cattle has been increasing at 2–4% per annum, while that of adult male cattle is almost stagnant. Adult female cattle account for 80% of the total adult cattle population in the country. This holds true for all CLSs. Buffaloes comprise about one half of cattle population, and as in the case of cattle, adult female buffaloes account for 70% of the total adult buffalo population. Similar trends have been observed in CLSs 1, 2 and 3, where buffaloes are important.

Between 1982 and 1998, the population of adult female buffaloes increased significantly at 3.7% per annum. An increase was also observed in female buffalo populations in most CLSs. Goat population however grew fastest in all the systems during this period. On the whole, goat population witnessed a robust growth of 10% per annum. Poultry population also increased everywhere, the average rate of increase being 5% per annum (Table 6.6 and Appendix 6.2).

Table 6.6. Growth in livestock population (% per annum), Sri Lanka, 1982–1998.

Systems	Adult male cattle	Adult female cattle	All cattle	Adult male buffalo	Adult female buffalo	All buffalo	Ovines	Poultry
1	1.40	2.75	1.38	1.19	5.89	3.77	8.77	3.63
2	-1.62	1.41	-0.51	-2.52	1.05	-0.59	10.86	4.98
3	0.72	2.82	1.47	0.40	4.56	3.05	11.59	7.56
4	2.37	2.07	0.81	-2.41	1.67	-0.54	9.48	3.64
5	2.91	2.54	1.02	-1.05	1.22	-0.24	8.60	5.03
6	2.36	4.91	2.68	1.31	7.62	5.43	20.93	2.92
All systems	**0.71**	**2.51**	**0.95**	**-0.67**	**3.72**	**1.83**	**10.03**	**5.04**

6.2.4. Changes in the Composition of Livestock Population

Between 1982 and 1998, the composition of livestock population underwent changes due to technological and socio-economic factors. The ratio of adult female bovine to male bovine increased in all systems, indicating a shift towards milch animals and a decrease in draft animals due to mechanization. The average ratio increased from 2.14 in 1980 to 3.28 in 1998 (Table 6.7 and Map 6.4). There was a decline in the ratio of cow to she-buffaloes (average for all zones); however the decrease was less dramatic and the ratio actually increased in CLSs 4 and 5. Bovine to ovine ratio declined from 6.7 to 4.4 during this period. This phenomenon was universal (Map 6.5) and was due to faster growth in ovine population. With faster growth in livestock population, livestock pressure on cropland increased in all the systems. The average number of cattle-equivalent livestock units per ha of cropped area increased from 2 in 1982 to 2.8 in 1998. Grazing lands also came under pressure; the number of goats per ha of grazing area having almost doubled from 3 to 5.8 during this period. Livestock pressure in different systems is shown in Map 6.6.

Information on the share of purebred and crossbred cattle in different CLSs is limited. Household surveys by Ibrahim et al. (1999) indicate a high proportion of crossbred cattle (40–60%) in the mid and up country and wet low country nearer to the country's capital city Colombo. They also observed an increase in improved buffalo population to meet growing demand for milk, and not for draft purposes for which they are used.

Changes in the structure of livestock population indicate the growing importance of female bovines, increasing livestock pressure on limited land resources, growing importance of goats, particularly among poor smallholders, and declining use of animals for draft purposes. Although there is wide spatial distribution of animals, there is a tendency towards regional specialization. Pigs and poultry are becoming concentrated in CLSs 2 and 3, which have large urban populations. Indigenous cattle and buffalo are found mainly in the dry CLS 1 and 6. Similarly, goats are concentrated in the dry CLSs 1, 2 and 6. Dairy farming is important in CLSs 3, 4 and 5 in the low country wet, and mid- and hill country zones.

6.2.5. Feed Use

The dairy sector in Sri Lanka is dominated by smallholders who comprise about two-thirds of dairy farmers. Dairy animals primarily depend on pasture and fodder

Table 6.7. Density of livestock species and change in composition, Sri Lanka, 1980 and 1998.

System	Adult female bovine/ adult male bovine	Adult female cattle/ adult female buffalo	Bovines/ ovines	Ovines/ grazing land)	LU/ NCA[1]	Cattle/ NCA[1]	Buffalo/ NCA[1]	Bovine/ NCA[1]	Ovines/ NCA[1]	Cattle/ NCA[2]	Buffalo/ NCA[2]	Bovines/ NCA[2]	Ovines/ NCA[2]
				(no./ha)									
						1998							
1	3.71	2.37	4.54	6.22	3.22	1.33	0.62	1.95	0.43	1.33	0.62	1.95	0.43
2	2.79	1.99	4.05	28.84	5.96	2.22	1.27	3.50	0.86	2.35	1.34	3.69	0.91
3	3.69	1.83	4.33	25.93	1.21	0.47	0.27	0.74	0.17	0.97	0.56	1.53	0.35
4	3.01	5.74	2.92	3.19	1.49	0.76	0.14	0.90	0.31	2.15	0.40	2.55	0.87
5	3.63	2.48	3.40	3.77	2.28	0.92	0.43	1.35	0.40	1.29	0.61	1.90	0.56
6	2.70	2.25	12.16	1.04	4.08	1.74	0.73	2.48	0.20	1.77	0.75	2.52	0.21
All systems	**3.28**	**2.34**	**4.36**	**5.82**	**2.77**	**1.14**	**0.53**	**1.66**	**0.38**	**1.51**	**0.70**	**2.22**	**0.51**
						1980							
1	2.63	3.84	4.77	4.29	2.85	1.46	0.47	1.93	0.41	1.47	0.47	1.93	0.41
2	1.63	1.88	10.94	11.64	4.90	2.02	1.17	3.19	0.29	2.09	1.21	3.30	0.30
3	2.38	2.39	7.73	10.59	0.72	0.33	0.15	0.48	0.06	0.80	0.35	1.15	0.15
4	2.53	5.39	5.58	1.52	1.02	0.58	0.13	0.71	0.13	1.50	0.34	1.84	0.33
5	2.79	2.02	5.69	2.05	1.02	0.44	0.26	0.70	0.12	0.90	0.52	1.42	0.25
6	1.57	3.39	22.77	0.33	2.09	1.13	0.31	1.45	0.06	1.13	0.31	1.45	0.06
All systems	**2.14**	**2.82**	**6.66**	**3.13**	**1.97**	**0.94**	**0.38**	**1.32**	**0.20**	**1.39**	**0.56**	**1.96**	**0.29**

1. Net cropped area including area under tea and rubber.
2. Net cropped area excluding area under tea and rubber.

on farms or common property lands due to the limited area under cultivated pasture and fodder. Lack of good quality feed is a major constraint to profitable smallholder dairy enterprises. This is primarily the result of high pressure on land and competing opportunities for labor, which restrict the supply of fodder. Use of commercial compound feed is low; hardly 10% of dairy farmers use it. In addition, the feed milling industry is barely involved in producing compound feeds.

Feeding practices of livestock vary with agro-ecology and farming system. Animals are often grazed on paddy land (bunds and harvest aftermath), public spaces and under coconut trees, more so in the dry regions. In high-producing CLSs 3, 4 and 5, grazing is supplemented by stall feeding. The use of concentrate feed is low, except in CLS 3. For concentrate feeding, cows are preferred over buffaloes, as the latter in these systems are meant mainly for draft purposes.

In up country systems, plantation estates are common. Estate workers keep dairy cows, mainly improved European breeds under stall-fed conditions. Concentrate feeding is common. Since estate workers have no land of their own, they depend on natural grasses growing on canal bunds and wastelands for forage.

In CLS 5, cattle and goat are kept either in semi-intensive systems or tethered to trees. Forage is collected off-farm and concentrate feed is fed to milking animals. Generally, herd size is limited to two cows in production and their offspring. The use of buffaloes is common in small-scale rice production in low-lying areas.

CLSs 1 and 6 are rice-producing systems where rice is grown under irrigated as well as rainfed conditions. They are typified by the use of indigenous livestock breeds. Livestock production is extensive; animals graze for most of the year on paddy lands, bunds, tank beds, *villus* and scrub jungle. Use of concentrate feed is not common, although some farmers feed lactating cows rice bran. The use of natural tree fodder is common. In the recent past, lands that were used as natural grazing lands are being increasingly used for purposes such as development projects, wildlife sanctuaries, etc., thus limiting natural grazing lands and posing a major constraint to feed availability. Irrigated lands are fully occupied for most of the year. Crop residues are available in plenty, but their use as fodder is not common.

In coconut-based goat farming in the low country, wet and intermediate zones (CLSs 2 and 3), goats are reared in small herds of 4–12 under semi-intensive management. They are allowed free grazing mainly to control weeds under coconut trees. Feeding cows rice bran is common. Cut fodder is used when grazing is restricted due to cropping. Farmers who rely solely on stall feeding may be peri-urban producers or those rearing cattle in the confinement of the uplands, where manure is a major product of the system.

6.2.6. Technology Adoption

Artificial Insemination (AI): Although known to most livestock farmers, artificial insemination technology has not been all that successful. At the provincial level, the central province (CLSs 4 and 5) is ranked first, followed by the northwestern and western provinces. Though these provinces cannot be strictly compared with Crop-Livestock Systems, superimposing the CLS classification over provinces suggests better adoption of artificial insemination in CLSs 2, 3, 4 and 5. Kandy district in CLS 5 and Kurunagala district in CLS 2 rank high in the adoption of AI (DAPH 1998). Adoption has been found to be better in the central province since the climate is suited to improved animals, and farmers' are aware of the technology. Other breeding technologies such as pregnancy diagnosis are also better in this province (DAPH 1998).

Use of AI in cattle increased over time (Figure 6.1) but declined in goats. In Jaffna district with its large number of goats, AI has declined considerably during the last two decades. Use of AI in buffaloes has increased but the coverage is poor. AI technicians from the public and private sectors are attached to the range veterinary office from where they obtain semen doses. Changes in the number of AI technicians and the number of breedable cattle over time are shown in Figure 6.2.

According to a field survey, constraints to AI adoption include non-implementation of timely insemination, poor conception rate and thus repeated inseminations and lack of monitoring by veterinarians. An important constraint includes non-exhibition of heat signs by the animals (Abeygunawardena et al. 1995).

In 1981, about 3% of the cattle were reported belonging to improved breeds. But in a household survey in 1998, their proportion was 40% (Ibrahim et al. 1999). Private bull services and expanding markets for improved heifers from surplus areas have contributed to a rise in the population of improved cattle.

Urea Molasses Mineral Block (UMMB): Dairy buffaloes and cattle in Sri Lanka have traditionally been reared on locally available natural pastures and tree fodder. Their availability, however, is seasonal. During the dry period, both the quantity and quality of forage declines; so mature grasses and crop residues such as straw,

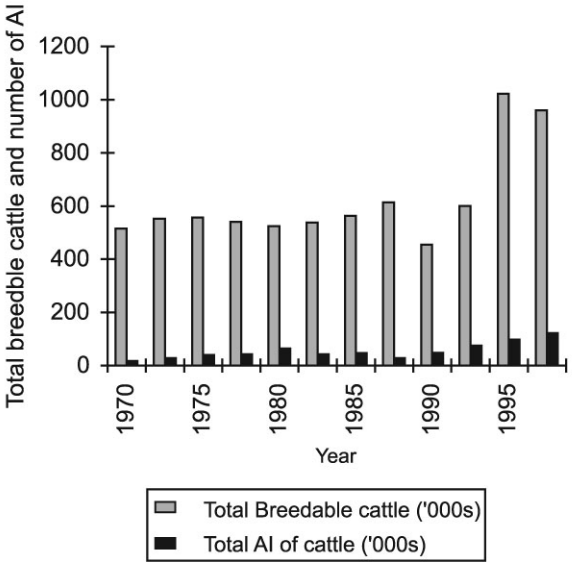


Figure 6.1. Variation in total breedable cattle and number of artificially inseminated cattle in Sri Lanka.

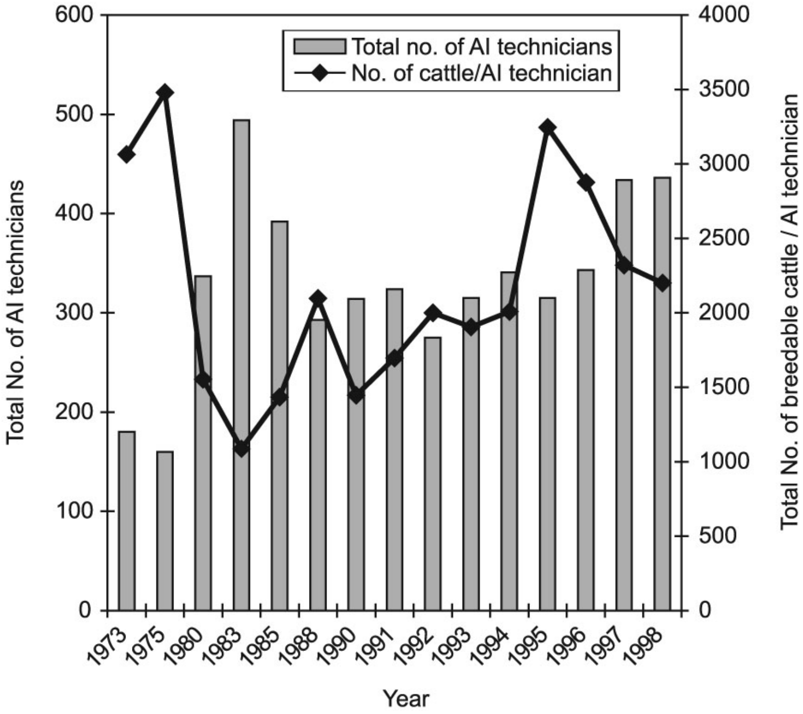


Figure 6.2. Artificial insemination technicians in Sri Lanka.

which are deficient in crude protein, soluble carbohydrates and minerals, are the only feeds available. They are low in digestibility and palatability. Urea Molasses Mineral Block supplements provide the nutrients that are missing in poor-quality roughage by enhancing microbial fermentation in the rumen, thereby improving intake, digestibility and utilization of forages and crop residues.

Though the importance of UMMB has been proven at the field level, its adoption is low, but demand is expanding. The major constraints encountered at the field level are over-licking, biting and eating of blocks by the animals. It has been recommended that the blocks be available to a cow throughout the day. This is, however, impossible to practice under semi-intensive type of management where animals are grazed most of the time. The Fodder Development Center's inability to continue manufacturing UMMB due to lack of funds is a major supply constraint. Moreover, private sector participation in UMMB manufacture is limited (Perera 1996; Siriwardana and Ade 2001; Subhasinghe 2001 and Nettasinghe 2001).

Urea treatment of straw: Animal nutritionists have successfully demonstrated the benefits of urea treatment of straw. However, its adoption is restricted to large farmers. Use of treated straw among small-scale and subsistence farmers is very low. Lack of extension support, accidents due to urea, lack of water and high cost are the major constraints (Ibrahim and Schiere 1986 and Ibrahim et al. 1986).

Rice bran: Rice bran is a widely used local feed ingredient fed directly to animals. Its chemical composition varies with rice variety (Palipana and Swarnasiri 1985), and its quality varies widely with milling practice. Non-conventional rice mills produce poor quality bran containing a higher percentage of husk, resulting in increased crude fiber content of up to 20–30%, whereas semi-modern and modern mills produce rice bran with crude fiber levels of 7–15%. High fiber content is a major problem in the formulation of adequate feed ration (Wickramaratne 1999).

6.2.7. Infrastructure

Road networks are better in CLSs 2, 3, 4 and 5 compared to CLSs 1 and 6. The density of dairy centers and veterinary institutions is also higher in CLSs 3, 4 and 5 (Table 6.8 and Maps 6.7 and 6.8). Dairy co-operatives provide wide-ranging services including credit to buy concentrate feeds and extension services. Generally, the density of diary co-operatives is low in dry CLSs, despite which these systems make a significant contribution to milk production.

Table 6.8. Selected infrastructural and agro-climatic variables, Sri Lanka, 1980 and 1998.

System	Road length (km/ sq. km of geog area)		Dairy co-operatives (no./'0000 LU)		Dairy centers (no./'0000 sq. km geog area)		Veterinary centers (no./'0000 LU)	Annual rainfall (mm)	Annual temperature (mean)
	1980	1998	1980	1998	1980	1998	1998		
1	0.32	0.27	0.13	0.57	0.73	0.36	0.48	1522	26.1
2	0.53	0.53	0.07	0.75	0.00	1.08	0.58	1708	24.6
3	0.71	0.72	0.35	0.39	2.89	5.78	1.21	2328	26.1
4	0.50	0.57	0.31	0.93	3.81	3.81	1.26	2522	21.2
5	0.66	0.69	0.30	1.44	5.09	2.54	1.08	1633	21.5
6	0.23	0.14	0.38	0.79	0.00	0.00	0.44	1879	21.0
All systems	**0.38**	**0.40**	**0.15**	**0.70**	**1.37**	**1.52**	**0.68**	**1843**	**24.3**

6.3. Production and Productivity

CLS 1 contributes the highest (40%) to total milk production in Sri Lanka, followed by CLSs 4 (20%) and 3 (14%). The share of other systems is around 10% each. Per capita milk production is also highest in systems 1 and 4, mainly due to low population density. However, despite high population density in CLS 4, per capita milk production is high, reflecting an intensive dairy production system (Table 6.9).

Table 6.9. Milk production and growth, Sri Lanka, 1970 and 1998.

System	Milk Production ('000 t)		Per capita milk (l/annum)		Milk production density/sq. km	Growth in milk Production	Growth in per capita milk
	1970	1998	1970	1998	1998	1970-98	
1	63.7	111.2	28.8	28.1	4.0	3.0	-0.1
2	14.2	28.5	10.1	12.9	4.1	3.7	1.3
3	47.3	39.8	8.8	5.3	4.4	-0.9	-2.6
4	23.3	59.4	13.5	25.1	7.5	5.1	3.3
5	19.4	22.7	12.9	12.5	5.8	0.8	-0.2
6	9.5	22.9	20.5	24.4	2.3	4.7	0.9
All systems	**177.5**	**284.5**	**14.0**	**15.6**	**4.3**	**2.5**	**0.4**

On the whole, milk production in Sri Lanka grew by 2.5% per annum between 1970 and 1998. CLSs 4, 6, 2 and 1 had significant growth rates in milk production[12]. Annual growth in milk production was the highest in CLS 4, largely driven by the adoption of improved breeds of cow. In CLS 3, growth in milk production was negative, while in CLS 5 it was less than 1% per annum. CLS 3 has a huge urban population, and the scope for expansion of dairying could be limited. However, this may have a favorable impact on dairying in the surrounding systems.

Per capita milk production has remained stagnant in other CLSs, high opportunity cost of labor and low milk prices being the main reasons. Ibrahim et al. (1999) found that the ratio of milk price (in formal markets) to wage rate (for unskilled labor) was 1:13 in Sri Lanka compared to 1:4 in India. Due to high opportunity cost of labor, it is uneconomical to use hired labor in milk production. Despite liberalization of market policies, smallholders are compelled to sell milk to processing plants at prices fixed by the government. Imports of dairy products increased due to liberal trade policies, further weakening domestic markets (Devendra et al. 2000).

Milk yield has generally been low, ranging from 1 to 3 l per day in rainfed rice systems, mainly due to shorter lactation, poor feeding and poor quality of animal genetic resources. Milk yield in the estate-based systems was higher, ranging from 6 to 15 l per day, primarily due to higher population of exotic and crossbred cows, and the practice of stall feeding. Milk yields varied from 4 to 6 l per day in the coconut-based CLSs 2 and 3, where the semi-extensive system of management is practiced. Buffalo milk yield is about 2 l per day.

6.3.1. Factors influencing productivity

Detailed information for analyzing the determinants of milk and meat productivity is not available. Using information available, correlation coefficients between milk productivity and some key variables have been estimated in Table 6.10. Milk yield is higher in CLSs having better infrastructure. The correlation between cow milk yield and veterinary institutions is positive and significant. Its association with road and dairy co-operatives is also positive and significant. Buffalo milk yield, on the other hand, is high in areas with a larger proportion of urban population

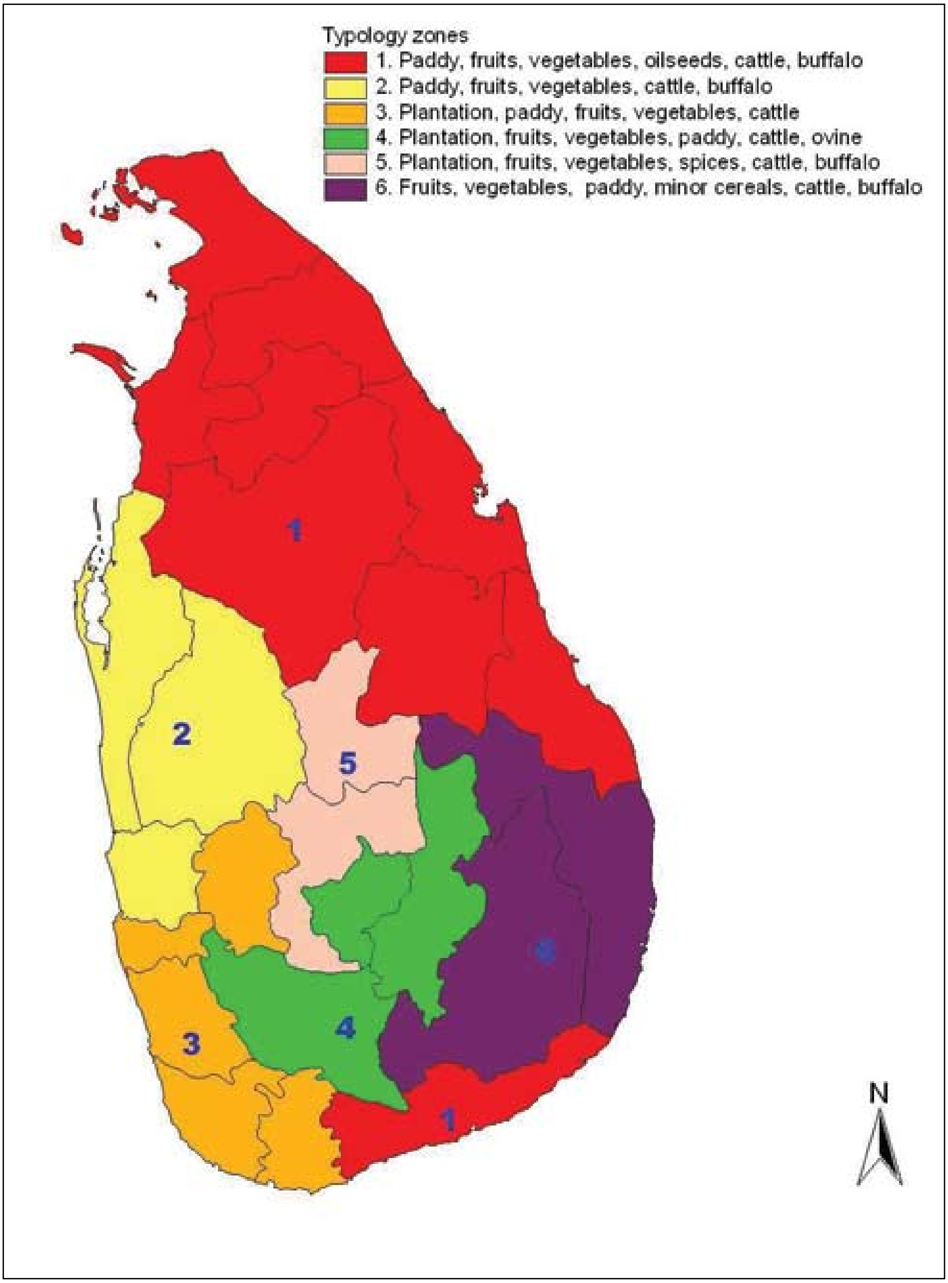
[12] Data on livestock numbers, milk production, etc., need to be interpreted cautiously. Different studies have reported a decline in livestock numbers and an increase in milk production between 1985 and 1995. Between 1980 and 1998, livestock numbers increased. Since data on milk production during 1980 were fraught with problems, growth rates in milk production were calculated between 1970 and 1998. Part of the inability in getting accurate data lies in the country's long civil strife.

where buffaloes are kept mainly for milk. However, since female buffaloes are also used for draft purposes, milk yield alone may not reflect the true productivity of buffaloes.

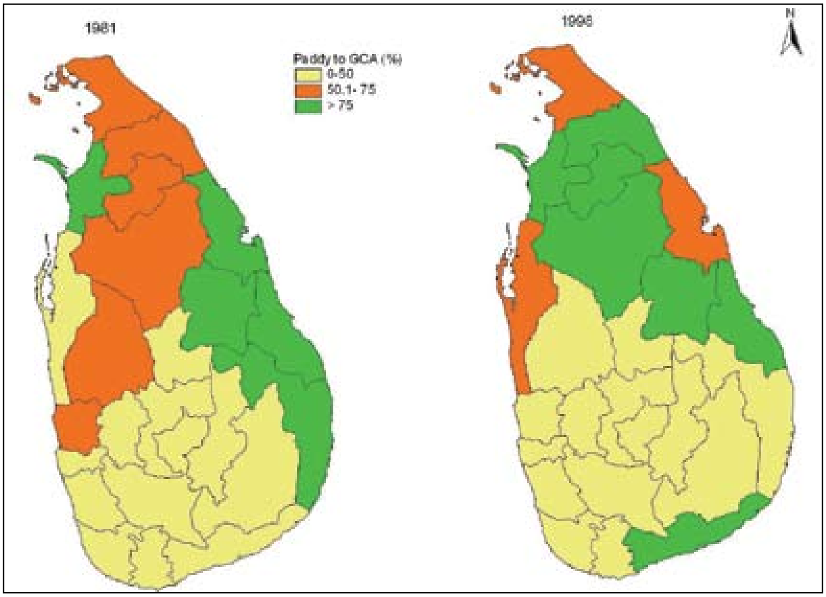
Table 6.10. Correlation between milk yield and selected variables in Sri Lanka.

Variables	Cow milk yield[1]	Buffalo milk yield[1]
Population density (no./sq. km of geographical area)	0.11	0.10
Urban population (% of total)	-0.07	0.45
Road density (km/'000 sq. km of geographical area)	0.44	-0.31
Veterinary institutes (no./'000 livestock unit)	0.43	-0.38
Dairy co-operatives (no./'000' livestock unit)	0.44	-0.47
Rainfall (mm)	0.10	-0.16

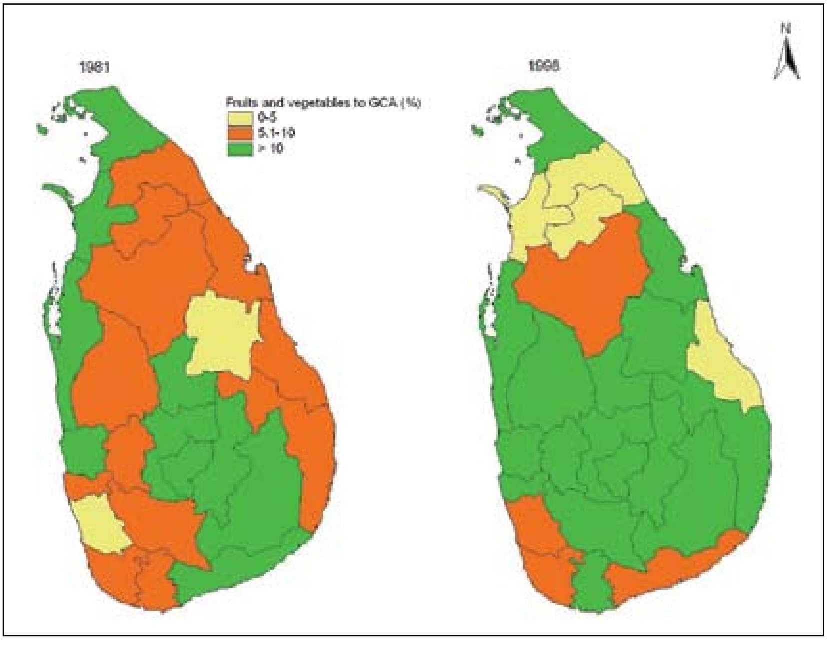
1. Yield refers to all milch animals i.e., dry and in milk (kg/animal).



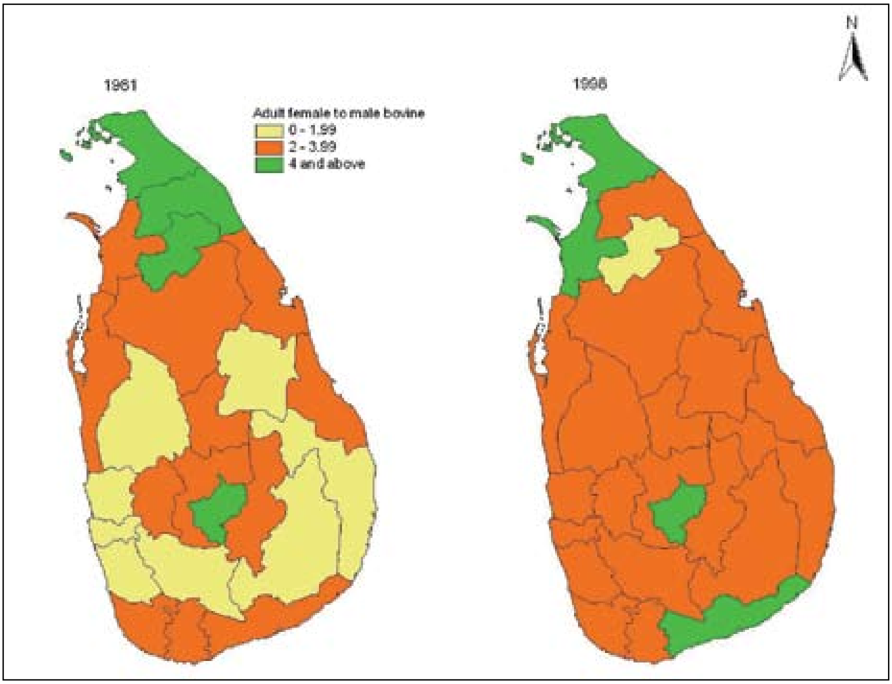
Map 6.1. Crop-Livestock Systems in Sri Lanka, 1998.



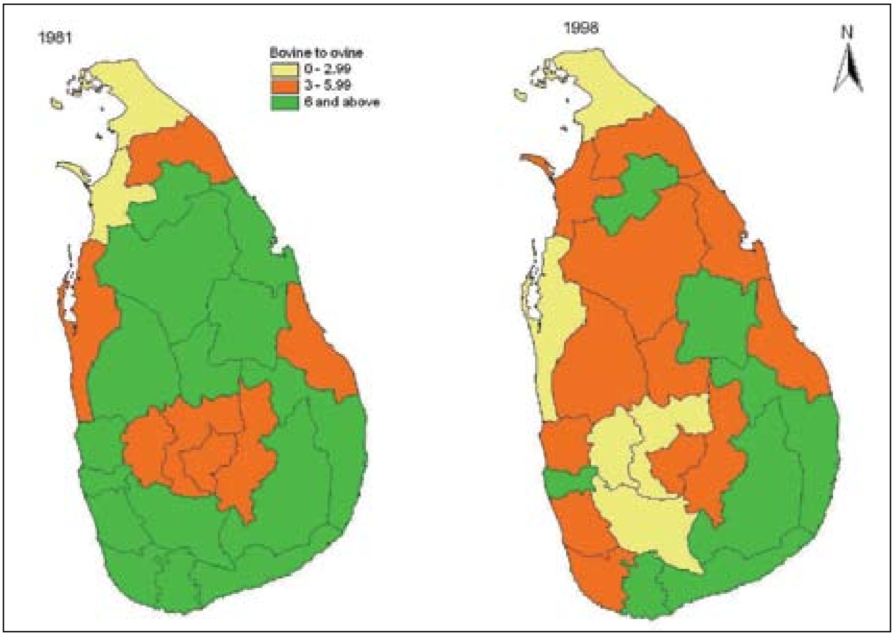
Map 6.2. The share of area under paddy in gross cropped area in Sri Lanka, 1981 and 1998.



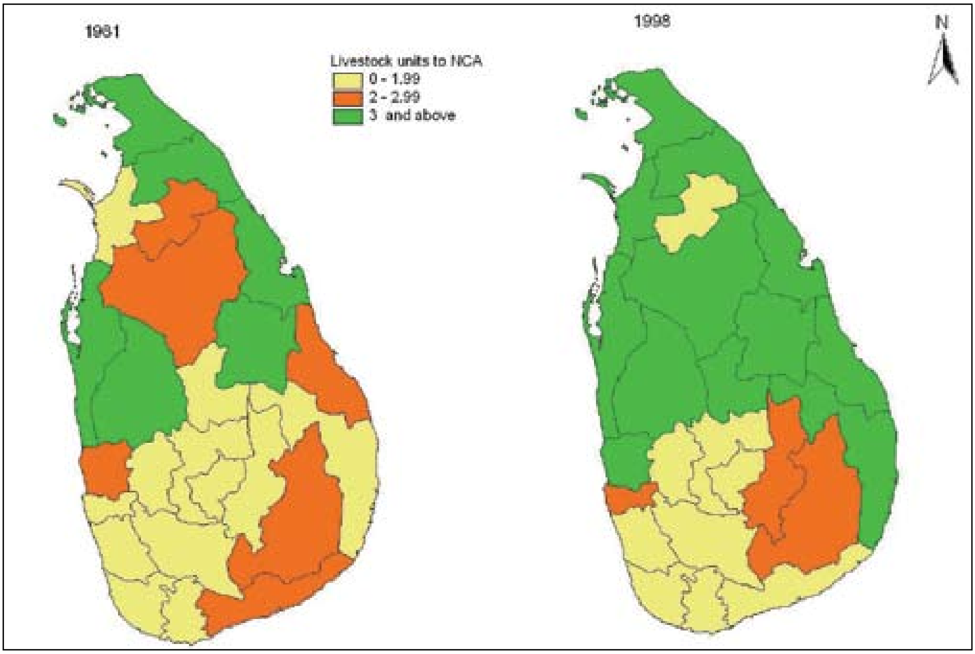
Map 6.3. The share of area under fruit and vegetables in gross cropped area in Sri Lanka, 1981 and 1998.



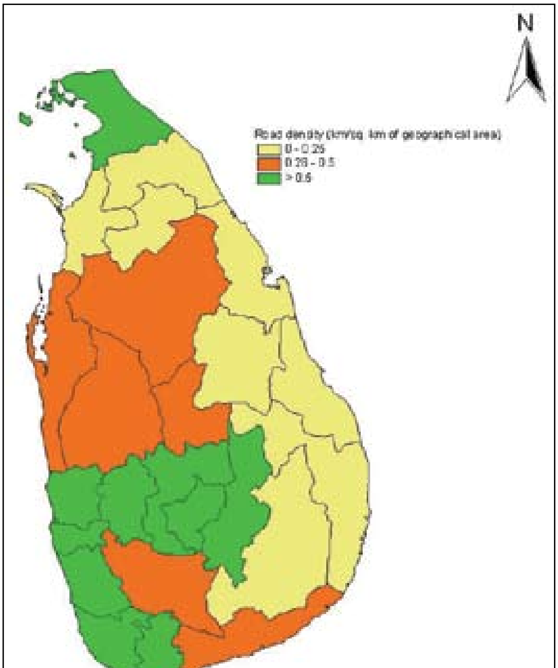
Map 6.4. Ratio of adult female bovines to male bovines in Sri Lanka, 1981 and 1998.



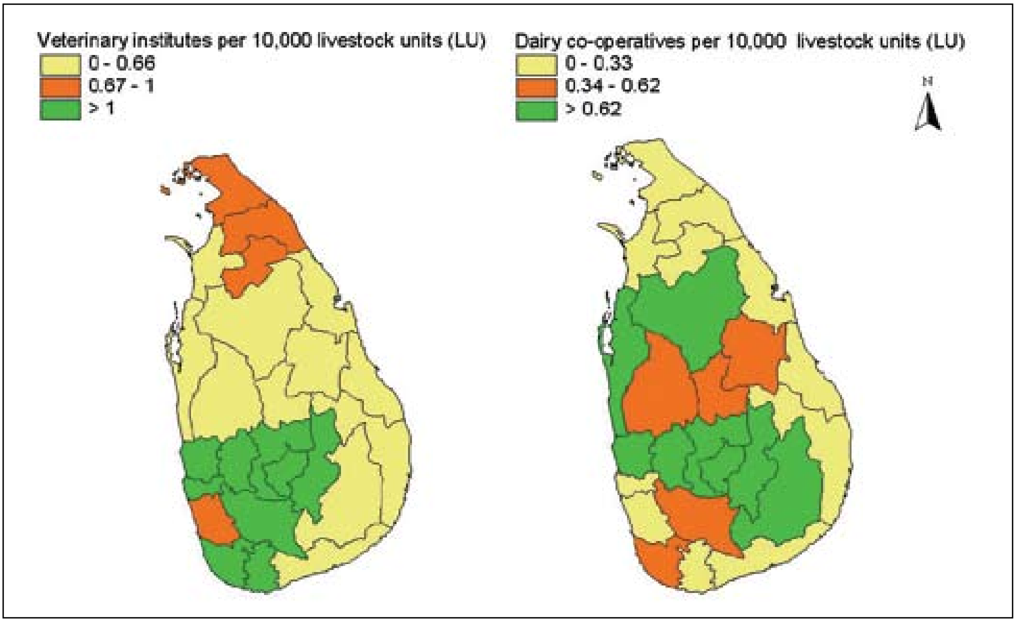
Map 6.5. Ratio of bovines to ovines in Sri Lanka, 1981 and 1998.



Map 6.6. Density of livestock units to net cropped area in Sri Lanka, 1981 and 1998.



Map 6.7. Density of roads in Sri Lanka, 1998.



Map 6.8. Density of veterinary institutes and dairy co-operatives in Sri Lanka, 1998.

Appendix 6.1. Area under crops (%) relative to gross cropped area[1] in Crop-Livestock Systems in Sri Lanka, 1980 and 1998.

System	Paddy	Other cereals	Pulses	Oilseeds	Root crops	Vegetables and fruits	Spices	Plantation	Coconut 2
					1998				
1	83.4	1.9	3.0	3.4	1.7	5.9	0.4	0.1	7.2
2	43.8	1.0	3.9	3.4	4.9	33.0	2.3	5.9	57.3
3	27.8	0.0	0.0	0.5	2.1	11.5	8.5	48.2	17.1
4	8.7	2.6	1.2	1.4	4.3	18.2	2.8	59.6	7.3
5	5.8	1.9	0.8	2.4	2.9	29.0	19.7	36.0	15.3
6	27.4	11.4	8.7	5.6	4.6	38.8	0.4	2.8	9.2
All systems	**48.8**	**2.1**	**2.4**	**2.6**	**2.8**	**15.3**	**3.9**	**21.3**	**20.4**
					1980				
1	72.0	2.6	4.4	9.2	3.6	7.5	0.4	0.1	9.8
2	58.6	1.6	7.2	7.1	7.2	13.0	0.4	3.2	50.6
3	32.6	0.1	2.0	0.7	3.6	6.3	4.6	48.1	14.0
4	20.1	3.9	1.7	2.1	4.9	12.1	1.2	53.1	4.8
5	25.0	3.5	0.7	3.4	2.5	12.6	4.1	46.6	7.2
6	62.4	6.3	3.7	7.3	5.5	14.2	0.1	0.2	5.9
All systems	**45.6**	**2.4**	**3.3**	**4.8**	**4.3**	**9.9**	**2.0**	**26.6**	**19.0**

1. Area under coconut excluded in gross cropped area.
2. Area under coconut included in gross cropped area.

Appendix 6.2. Livestock population ('000 numbers) in Crop-Livestock Systems in Sri Lanka, 1980 and 1998.

System	Adult male cattle		Adult female cattle		Total cattle		Adult male buffalo		Adult female buffalo		Total buffalo		Goat		Pig		Poultry	
	1980	1998	1980	1998	1980	1998	1980	1998	1980	1998	1980	1998	1980	1998	1980	1998	1980	1998
1	80	100	273	422	540	673	51	62	71	178	172	311	149	209	2	10	901	1,595
2	81	63	167	209	368	339	76	50	89	105	213	194	53	128	26	47	1,795	3,910
3	19	21	58	91	118	149	16	17	24	50	53	85	22	54	5	13	695	2,232
4	20	29	69	96	144	164	12	8	13	17	33	30	32	67	1	3	327	579
5	7	12	44	66	86	101	16	14	22	26	50	48	24	44	2	2	400	878
6	24	35	40	85	100	152	8	10	12	38	28	64	6	18	0	0	235	373
All systems	**232**	**259**	**651**	**969**	**1,356**	**1,579**	**180**	**162**	**231**	**414**	**548**	**733**	**286**	**519**	**37**	**76**	**4,354**	**9,566**

Chapter 7

Typology of Mixed Crop-Livestock Systems in Nepal

In Nepal, agriculture contributes 39% of the gross domestic product, of which livestock account for 29%. The country is broadly divided into three geographical eco-regions —Terai region, the hill region and the mountain region. The share of livestock is the lowest (20%) in the Terai region and highest (48%) in the mountain region. In the Terai and hill regions, livestock are raised mainly in Mixed Crop-Livestock Systems. About two-thirds of the livestock keepers are smallholders, having land holdings of less than 1 ha (Devendra et al. 2000). On an average, a livestock keeping Nepalese household owns 2.14 cattle, 1.79 buffaloes, 3.03 goats and 9.85 poultry birds (Rushton et al. 2005). Animals supply almost all the draft power requirements and are an important source of plant nutrients. Livestock survive mainly on crop residues and by-products, especially in the Terai and Mid-hills (Pradhan 1997). Grazing lands meet most of the feed requirements in the mountain region.

Nepal's wide diversity in climate and topography has contributed to the evolution of different Crop-Livestock Systems. Elevations in the country range from 100 m in the Terai to 8000 m in the Himalayan mountains. This study restricts itself to the Terai and hill regions since the mountain region accounts for only 4% of the cropped area. The animal production system in the mountain region is a low-input and extensive system based on pastoralism[13].

7.1. Crop-Livestock Systems Typology

Using the methodology described in chapter 4, a crop-livestock typology was constructed. What emerged is a six-system typology with distinct Crop-Livestock Systems, three of which were further sub-divided into two systems each to maintain their geographical contiguity. Thus a nine CLS typology has been constructed, four of which are in the Terai region and five in the hill region (Table 7.1 and Map 7.1).

Paddy is the dominant agricultural activity in all the four systems in the Terai region. Wheat is another important crop. Amongst different livestock species, cattle dominate all the systems in this region. In three of the five CLSs in the hill region, maize is the dominant crop (CLSs 3, 4 and 6). Wheat and paddy are the other important crops in systems 3 and 4. Paddy and millet are also grown in CLS

[13] The mountain region is treated as one zone/system and the data are reported in all tables merely for the sake of comparison with the systems in the Terai and hill regions.

6. Wheat is the dominant crop in systems 5a and 5b. Cattle are important in these systems. On the other hand, small ruminants are important species in CLSs 3 and 6. Buffalo, in terms of numbers, occupies third place in livestock population, but its share in the value of livestock sector output is much higher.

Table 7.1. Agricultural activity-based systems in a crop-livestock typology, Nepal, 1998.

System	No. of districts	Location (province)	Region[1]	Major crop[2] and livestock activities[3]
1a	5	Terai	Central (5)[4]	Paddy (43), wheat (19), pulses (14), ovines and cattle
1b	6	Terai	FW (2), MW (3) and West (1)	Paddy (42), wheat (18), pulses (14) and cattle
2a	2	Terai	West (2)	Paddy (60), wheat (21) and cattle
2b	7	Terai	Central (2) and East (5)	Paddy (65), wheat (16) and cattle
3	9	Hills	MW (7) and West (2)	Maize (39), wheat (25), paddy (18) and ovines
4	4	Hills	East (4)	Maize (39), paddy (27), wheat (11) and cattle
5a	4	Hills	FW (4)	Wheat (34), paddy (26), maize (20) and cattle
5b	4	Hills	Central (4)	Wheat (31), paddy (27), maize (24) and cattle
6	18	Hills	Central (5), East (4) and West (9)	Maize (38), paddy (25), millet (19) and ovines
Mountain	16	Mountain	All regions	Maize (27), paddy (18), wheat (18), millet (18) and ovines

1. Development regions: Central, FW (Far West), MW (Mid West), East and West.
2. Percentage of GCA.
3. Livestock density to cropped area
4. Figures in parentheses are number of districts in each region.

7.2. Characteristics of Crop-Livestock Systems

7.2.1. Geographical Dispersion

The mountain region is spread over 37% of Nepal's geographical area but shares only 7% of the net cropped area. CLS 6 in the hill region has a larger share in net cropped area (23%). Systems 1a, 1b, 2a and 2b in the Terai region have a lower share of geographical area, but a larger share of the cropped area. Together these CLSs account for only 22% of the geographical area but 50% of the cropped area. In contrast, the mountain region accounts for a bulk of the grazing land (65%).

CLSs 3 and 6 in the hill region follow with a share of 11% and 16% respectively. These systems also have a large share of barren land (14% and 31% respectively)[14]. On the other hand, the area under grazing and barren lands is almost negligible in systems in the Terai region (Table 7.2).

Population density is high in CLSs in the Terai region and in CLS 5b in the hills. These are the better-endowed regions with high irrigation levels (Table 7.2). Between 1981 and 1998, population density increased very quickly in these systems. Population density also increased in CLSs 4 and 6 in the hills. Growth in population led to sub-division of land, further reducing average land size.

Population density is lowest in CLSs 3 and 5a located in the mid-west and far west development regions. The central and eastern development regions have a high urban population and account for 70% of the total urban population in Nepal while the western region accounts for 16% of it.

Table 7.2. Relative importance of land use and selected indicators in Crop-Livestock Systems in Nepal, 1999.

System	Geographical area	NCA[1]	GCA[2]	Barren land	Grazing land	Human population	Population density (per sq. km)	Urban population (%)
	% to all systems							
1a	4.8	10.5	13.7	3.1	1.2	11.3	340.61	11.7
1b	8.2	12.4	15.2	4.8	1.9	12.3	218.12	12.6
2a	2.1	6.4	5.5	1.2	0.1	5.2	352.73	13.0
2b	6.8	19.6	19.5	6.0	1.0	19.8	422.65	13.4
3	11.0	9.6	8.5	14.0	11.1	8.4	110.98	3.7
4	3.7	5.3	4.5	6.3	0.9	4.0	158.12	8.1
5a	4.5	3.3	2.5	5.7	2.7	3.4	107.28	5.1
5b	1.6	2.7	3.0	3.3	0.2	8.3	767.24	51.6
6	20.4	22.6	21.5	30.9	16.1	20.0	142.86	11.0
Mountain	36.8	7.6	6.1	24.6	64.7	7.2	28.57	0.0
All systems[3]	**14,831**	**2,795**	**3,837**	**1,109**	**1,756**	**21,554**	**145.33**	**13.7**

1. NCA = Net Cropped Area.
2. GCA = Gross Cropped Area.
3. Geographical area, NCA, GCA, barren land and grazing land in '000 ha and human population in '000 numbers.

[14] The hill farming system is classified into three vertical zones: the rice zone or lower hill belt from 500 to 1800 m above sea level (ASL); the maize/millet zone or upper hill belt from 1800 to 2500 m asl; and the potato, barley and buck wheat zone or high hill belt above 2500 m asl (Shrestha and Gautam 1999). Since the present study is based on district-level data, differences due to elevation have not been taken into consideration. In any case, strategies for the hill zones should be based on elevation level. The high hill zone farming system resembles those in the foothills of the mountain, characterized by less dependence on Mixed Crop-Livestock Systems.

7.2.2. Crop and Livestock Production

Paddy occupies the largest area in the country, followed by coarse cereals and wheat. Pulses, oilseeds, vegetables and potato are the other important crops. CLSs in the Terai region account for the bulk of paddy (75%) and wheat areas (57%). CLSs 3 and 6 in the hill region share a major chunk of the area under coarse cereals like millets and maize. In the case of pulses and oilseeds, the systems in the Terai region account for a major share in area, followed by CLS 6, which also has the highest area under fruits (27%) and CLSs 2b, 3 and 1a. CLS 2b in the Terai region has the largest share in vegetable area (23%) followed by systems 1a, 6, 5b and 1b (Table 7.3).

Cattle are the dominant livestock species (7 million heads) in Nepal, followed by goats (6.2 million), buffaloes (3.4 million) and sheep (0.85 million). Most sheep population is concentrated in the mountain region (43%). CLS 6 accounts for 31% of buffaloes, 23% cattle, 21% work animals, 28% goats and 23% sheep. All CLSs in the Terai region (except 2a) and CLS 3 in the hills contain a sizeable livestock population (Table 7.4). CLS 6 is the largest system in Nepal making a major contribution to livestock production. Approximately 30% milk, 25% meat and 21% egg outputs come from this system. Systems 1b and 2b in the Terai region and 3 in the hills are also important for dairying activity. Meat is important in CLSs 6, 1b and 2b in the Terai region and 5b in the hill region. Egg production is vital in CLSs 5b, sharing 22% of the total production in the country mainly due to the high urban population in this system.

Table 7.3. Relative importance of crops, Nepal, 1999.

	Paddy	Wheat	Coarse cereals	Pulses	Oilseeds	Cash crops	Fruits	Vegetables
System	% to all systems							
1a	15.1	15.6	5.3	29.0	21.0	19.0	9.9	21.4
1b	16.1	15.7	7.0	31.6	36.2	11.2	8.1	9.9
2a	9.3	6.9	0.2	3.3	4.1	6.2	4.2	4.4
2b	32.4	18.5	4.9	12.7	17.7	14.0	15.3	22.6
3	4.0	12.6	14.7	3.3	4.5	4.8	10.2	7.0
4	3.0	2.9	7.6	2.5	3.9	7.0	5.6	3.8
5a	1.7	5.1	2.7	2.0	1.3	1.5	4.3	1.4
5b	2.1	4.4	4.0	1.5	1.4	3.4	4.1	10.0
6	13.5	12.0	42.9	11.0	8.6	19.4	26.8	14.9
Mountain	2.8	6.3	10.7	3.2	1.3	13.4	11.5	4.6
All systems[1]	**1507**	**647**	**1094**	**250**	**179**	**159**	**63**	**147**

1. Crop area in '000 ha.

Table 7.4. Relative importance of livestock, Nepal, 1999.

System	Buffalo	Cattle	Work animals	Goat	Sheep	Livestock units[1]
	% to all systems					
1a	7.0	6.7	8.5	7.5	0.5	7.8
1b	12.0	13.6	17.3	7.8	9.6	14.7
2a	3.7	4.8	5.9	2.5	0.9	4.9
2b	11.5	14.4	17.9	12.8	1.3	15.2
3	12.4	13.8	11.9	14.3	15.6	12.4
4	4.0	5.3	4.5	5.2	3.2	4.5
5a	5.9	5.1	4.6	3.9	0.3	4.9
5b	3.5	2.2	2.2	4.3	2.4	2.6
6	30.9	22.7	21.3	27.7	23.1	23.9
Mountain	9.1	11.5	5.8	14.0	43.0	9.1
All systems[2]	**3,471**	**7,030**	**1,859**	**6,205**	**855**	**5,168**

1. Based on calculations by Shrestha and Sherchand (1998).
2. Buffalo, cattle, work animals, goat, sheep and livestock units in '000 numbers.

7.2.3. Growth in Crop Area and Livestock Population

Between 1980 and 1998, the area under all major field crops increased between 1.5 and 4% per annum. Growth rates were higher for coarse cereals, sugarcane, wheat and oilseeds. The area under paddy grew faster in CLSs 5a and 3 in the hills, but from a low base. Similarly, the area under wheat (except in CLSs 2b and 6) grew faster in the less-important wheat-growing systems (3, 4 and 5a). In contrast, growth rates were the highest for coarse cereals in CLSs 6 and 3, important coarse cereal-growing systems. The area under sugarcane, pulses and oilseeds increased in the CLSs in the Terai region, where these crops have a higher share in area, indicating a greater tendency towards commercialization of the crop sector (Table 7.5 and Appendix 7.1). National-level statistics also reveal that the area under horticulture is increasing rapidly, primarily in response to growing export demand (Pokharel 2003).

The population of adult male cattle declined in all the CLSs, more so in the hills. On an average, the population of adult cattle declined at 1.6% per annum, while the population of adult female cattle increased by 2.3% (Tables 7.6 and 7.7). The average density of work animals is 0.7/ha of cropped area. The decline in work animal density was because of a decline in land holding size due to the growing importance of nuclear families and the shortage of feed and fodder. Although work animals are indispensable in the hill systems, where mechanization cannot replace draft power, it is possible to hire animals to meet seasonal needs (Lawrence and Pearson 2002).

Table 7.5. Growth (% per annum) in crop area, Nepal, 1980–1998.

System	Paddy	Wheat	Maize	Millet	Barley	Sugarcane	Pulses[1]	Oilseeds
1a	0.16	1.87	2.10	-4.81	-5.72	3.09	2.85	22.01
1b	1.43	2.37	1.24	-0.63	-7.55	5.73	1.93	14.39
2a	0.38	-0.29	-6.56	-15.76	-11.94	4.61	-0.55	22.47
2b	0.09	3.62	2.71	-0.68	-7.89	3.59	1.65	2.97
3	3.34	4.19	4.83	0.73	3.73	-1.85	1.39	-3.06
4	0.82	4.96	3.71	2.39	-1.97	-0.38	3.00	10.76
5a	2.94	3.38	2.41	2.17	2.44	9.35	2.78	-2.16
5b	0.28	0.32	-0.15	1.90	-4.51	-5.30	0.51	-7.16
6	3.00	3.40	3.70	8.86	0.72	0.47	2.42	-4.40
Mountain	2.77	5.23	2.46	2.47	6.61	2.65	2.73	-12.41
All systems	**1.50**	**2.71**	**3.02**	**4.31**	**1.57**	**3.76**	**2.11**	**2.55**

1. Area under pulses was not available for 1981. Data for 1991 was taken and 10% subtracted uniformly from all districts to generate 1981 data.

The number of adult female cattle increased everywhere, but the growth in the she-buffalo population was quicker (3.2% per annum). Improved buffaloes are more adaptable to the environment and feed resources than improved cattle, particularly in the hill zones. Higher milk price, higher disposal value and urban consumers' preference for buffalo milk are the other factors attributed to this trend. Private traders play an important role in marketing improved buffaloes from the plains to the hill zones. About 30% of the buffaloes in Nepal are the Murrah and its crosses (Pradhan 1997).

Table 7.6. Livestock population (in '000 numbers), Nepal, 1998.

System	Adult male cattle	Adult female cattle	Total cattle	Adult male buffalo	Adult female buffalo	Total buffalo	Goat	Sheep
1a	143	173	468	16	142	242	466	4
1b	292	354	957	29	235	415	485	82
2a	102	124	335	8	75	128	156	8
2b	308	373	1,009	26	233	399	793	11
3	188	479	967	35	227	432	886	134
4	72	185	372	11	73	140	326	27
5a	69	178	358	16	108	205	242	3
5b	31	78	158	10	64	121	265	20
6	310	792	1,597	86	563	1,072	1,717	198
Mountain	105	324	809	3	147	317	870	368
All systems	**1,619**	**3,060**	**7,030**	**240**	**1,866**	**3,471**	**6,205**	**855**

Table 7.7. Growth (% per annum) in livestock population, Nepal, 1980–1998.

System	Adult male cattle	Adult female cattle	Total cattle	Adult male buffalo	Adult female buffalo	Total buffalo	Goat	Sheep	Milk[1]	Meat[2]	Egg[2]
1a	-1.11	0.01	-0.90	5.49	3.52	2.09	2.18	-7.91	4.54	5.57	8.08
1b	1.65	2.80	1.87	7.71	5.07	3.81	4.95	1.42	4.84	6.54	3.28
2a	0.60	1.74	0.82	5.41	3.44	2.01	2.73	2.76	2.82	0.87	7.29
2b	0.18	1.32	0.40	6.50	4.51	3.06	2.18	3.13	3.42	4.72	2.34
3	-3.23	2.91	0.20	10.14	2.18	1.38	4.25	0.96	0.77	2.68	1.18
4	-1.78	4.45	1.70	12.39	4.27	3.45	1.42	-0.28	4.33	4.08	0.06
5a	-2.79	3.37	0.65	13.90	5.67	4.84	2.48	1.14	1.93	6.80	2.04
5b	-4.83	1.20	-1.46	9.78	1.85	1.05	1.41	-2.83	2.51	6.24	3.32
6	-2.81	3.35	0.63	10.60	2.60	1.80	3.10	0.75	-5.25	-1.95	0.03
Mountain	-4.38	0.93	0.35	-1.73	1.56	1.21	3.52	2.56	1.71	1.82	-1.98
All systems	**-1.60**	**2.34**	**0.54**	**8.59**	**3.20**	**2.23**	**3.00**	**1.30**	**2.75**	**4.25**	**2.05**

1. Growth rate from 1986 to 1998.
2. Growth rate from 1991 to 1998.

These changes mainly occurred in areas with access to main highways and within reasonable distance from urban centers. The increase in improved buffalo population was demand-driven compared to the Government's supply-driven program to introduce crossbred cattle (Tulachan and Neupane 1999). Only about 5% of the cattle population belong to crossbreeds such as Jersey, Holstein, Friesian Brown Swiss and their crosses (Pradhan 1997). District-level data on improved cattle and buffalo are not available. Regional-level data indicate that the proportion of improved cattle and buffaloes is high in the central region (63% and 44% respectively), followed by the eastern region (25 and 22% respectively). In the case of poultry in the eastern region, 80% of the birds are improved poultry (NARC 2002). The goat population increased in all the CLSs because of their adaptability to varied environments, even in the extensive nomadic and transhumance systems in the hills and mountains. Other factors that influenced population increase were the high demand for goat meat and the easy marketability of live goats.

7.2.4. Changes in the Composition of Livestock Population

Between 1980 and 1998, the ratio of adult female bovine to adult male bovine increased in all zones indicating a rising demand for milk. The ratio was higher in all the CLSs in the hill region compared to the systems in the Terai region, perhaps implying the importance of work animals in the latter, where they account for 52%

of the total male cattle (Map 7.2). Although machines are replacing draft animals, most poor smallholders still depend on draft animals for agricultural operations (Shrestha and Gautam 1999).

Despite the growing importance of female buffaloes unlike in India, the average ratio of adult female cattle to adult female buffalo increased from 1.4 to 1.6 (Table 7.8). The ratio declined in CLSs in the Terai region but increased in all the CLSs in the hills. Thus adult female buffaloes are becoming relatively more important in the Terai region, particularly in CLSs 1a and 2b in the central and eastern development regions. The density of cattle, buffalo and ovine per ha of cropped area is higher in the hills compared to the Terai region, except in CLS 1b, where it is marginally higher (Table 7.9 and Map 7.3).

Table 7.8. Relative importance of livestock species, Nepal, 1980 and 1999.

	Adult female bovines to adult male bovines		Adult female cattle to adult female buffalo		Bovines to ovines		Density of LU to barren + grazing land		Density of ovines to barren + grazing land		Density of ovines to grazing land	
System	1980	1999	1980	1999	1980	1999	1980	1999	1980	1999	1980	1999
1a	1.5	1.7	1.7	1.2	2.1	1.5	7.0	7.2	6.0	8.4	15.7	22.0
1b	1.5	1.6	1.6	1.5	3.4	2.4	5.6	8.8	3.1	6.6	8.0	17.0
2a	1.5	1.6	1.6	1.7	3.8	2.8	13.1	16.4	6.5	10.5	51.8	84.1
2b	1.4	1.6	2.0	1.6	2.2	1.8	7.6	9.3	6.5	9.5	30.8	45.5
3	1.4	2.5	1.3	2.1	2.4	1.4	1.7	1.8	1.5	2.9	2.7	5.2
4	1.3	2.4	1.8	2.5	1.3	1.5	2.0	2.7	3.3	4.2	17.9	22.5
5a	1.3	2.5	1.8	1.7	2.6	2.3	1.7	2.3	1.4	2.2	3.3	5.1
5b	1.6	2.6	1.0	1.2	1.3	1.0	3.5	3.2	5.8	6.9	56.8	67.6
6	1.7	2.5	0.9	1.4	1.9	1.4	1.6	2.0	1.9	3.1	4.1	6.8
Mountain	1.8	2.5	1.7	2.2	1.5	0.9	0.3	0.3	0.5	0.9	0.6	1.1
All systems	**1.5**	**2.1**	**1.4**	**1.6**	**2.0**	**1.5**	**1.5**	**1.8**	**1.5**	**2.5**	**2.5**	**4.0**

The ratio of bovines to ovines declined in all CLSs. Generally, this ratio is low compared to other South Asian countries, indicating a fair amount of balance between bovine and ovine populations in Nepal (Map 7.4). Ovine pressure on grazing resources has been increasing in the Terai region owing to the limited availability of grazing lands and also in all the hills (Map 7.5). This has led to very high levels of soil erosion and an increase in noxious weeds (Devendra et al. 2000).

Table 7.9. Density of bovines, work animals and ovines (per ha cropped area), Nepal, 1998.

Systems	Density of cattle	Density of buffalo	Density of ovines	Density of work animals	Density of LU
1a	1.59	0.82	1.60	0.54	1.37
1b	2.76	1.20	1.64	0.92	2.19
2a	1.88	0.72	0.92	0.62	1.43
2b	1.84	0.73	1.47	0.61	1.44
3	3.61	1.61	3.81	0.83	2.39
4	2.51	0.94	2.38	0.56	1.57
5a	3.93	2.25	2.68	0.94	2.79
5b	2.07	1.58	3.73	0.53	1.73
6	2.52	1.69	3.03	0.63	1.95
Mountain	3.83	1.50	5.86	0.51	2.23
All systems	**2.52**	**1.24**	**2.53**	**0.67**	**1.85**

7.2.5. Feed Use

Crop residues are the major sources of feed, contributing about 40–50% of total feed. In the hill systems, besides crop residues the major sources of feed are rangelands, forest, shrub lands, cut grasses from forest and cultivated land, tree leaves from forest and fodder trees grown in cultivated lands (Tulachan and Neupane 1999 and Shrestha and Pradhan 1996).

Feed availability (crop residues and concentrates) is high in all the CLSs in the Terai region, compared with systems in the hills (except CLS 5b). The amount of feed available in dry matter is 2.3 t per livestock unit (Table 7.10). The correlation between feed availability with irrigation, fertilizer use and improved seed is positive and significant. The proportion of area irrigated and intensity of fertilizer and improved seeds use are high in CLSs in the Terai region compared to that in the hills, in which only CLS 5b has 22% of the crop area under irrigation, and use of fertilizer and improved seed is moderate.

Between 1981 and 1998, feed availability increased in all the CLSs except CLSs 1b and 2a in the Terai region, where it remained almost constant (Map 7.6). Total digestible nutrients (TDN) from grazing and barren lands per cattle equivalent are 3–4 times higher in the hills, partially compensating for lower feed availability from crop sources. Crop residues and fallow grazing contribute only 27% of total feed in the hills and less than 10% in the mountains (Devendra et al. 2000).

Table 7.10. Feed availability and inputs, Nepal, 1998.

System	Livestock feed (crop residues+ concentrates) t/LU		Fertilizer (kg/ha)	Irrigated area to cropped area (%)	Improved seeds (kg/ha)
	1981	1998	1996-97	1996-97	1996-97
1a	3.22	4.09	50.50	50.61	3.32
1b	2.18	2.3	48.71	39.43	1.21
2a	2.76	2.93	51.64	40.13	4.02
2b	2.63	3.34	50.40	50.73	2.56
3	0.7	1.49	16.07	4.88	0.08
4	1.73	2.03	14.68	7.36	0.31
5a	0.78	1.11	8.17	3.64	0.02
5b	3.17	3.49	286.25	22.07	1.65
6	1.12	1.85	31.55	6.74	0.51
Mountain	0.76	1.19	22.07	8.19	0.40
All systems	**1.71**	**2.28**	**43.83**	**26.46**	**1.48**

7.2.6. Technology Adoption

Adoption of yield-enhancing technologies is weak in Nepal. Most CLSs lack breeding bulls and barely 5% of cattle belong to high-producing breeds. In addition, artificial insemination services are not timely.

Cultivation of fodder is restricted due to the non-availability of tree fodder saplings and improved pasture seeds. Fodder production practices too are not standardized. Farmers lack information on silage/hay making and balanced feed formulation.

Animal health is poor due to lack of widespread veterinary infrastructure. Preventive vaccination is rarely practiced and diseases cause heavy losses. The cost of curative treatment is high and unaffordable by a majority of the farmers.

7.2.7. Infrastructure

Crop Livestock System 5b, which includes the capital city Kathmandu, has the highest density of roads, animal health and breeding services and dairy co-operatives as measured per cattle-equivalent livestock unit (Table 7.11). By and large, infrastructure facilities are better in the CLSs in the Terai region compared to those in the hills. The density of overall infrastructure is low in CLS 1b in the Terai region. Regarding health services, the present infrastructure can only serve 10–15% of the livestock population (Pradhan 1997). Further, most of it is located close to major urban centers (Pradhan 1997). Road network, an important factor determining access to markets, is poor in the hills.

Table 7.11. Density of infrastructure, Nepal, 1999.

System	Roads (km/'000 sq. km)	Markets (no./'000 sq. km)	Veterinary centres (no./'000 LU)	AI centres [no/'000 LU (catl + buff)]	Dairy co-operatives (no./'000 LU)	Multipurpose co-operatives (no./'000 sq. km)	Credit co-operatives (no./'000 sq. km)
1a	168.11	26.18	0.19	0.03	0.61	65.04	12.53
1b	129.21	5.41	0.11	0.02	0.07	12.55	8.20
2a	164.34	32.49	0.13	0.05	0.19	51.10	3.47
2b	196.41	38.13	0.14	0.04	0.09	41.50	14.26
3	57.31	0.61	0.17	0.01	0.05	4.52	5.37
4	112.05	10.47	0.20	0.02	0.07	13.78	21.12
5a	68.78	0.00	0.19	0.01	0.00	6.24	3.71
5b	477.31	0.43	0.42	0.26	2.11	71.68	109.46
6	59.68	3.08	0.20	0.02	0.15	10.33	12.05
Mountain	12.52	1.26	0.40	0.01	0.17	2.75	1.43
All systems[1]	**73.47**	**6.55**	**0.19**	**0.03**	**0.20**	**13.63**	**8.56**

1. Figures represent weighted averages

7.3. Production and Productivity

Buffaloes account for 70% of total milk production in most CLSs. In CLS 4, however, cattle are as important as buffaloes (Table 7.12). Between 1986 and 1998, milk production increased by nearly 3% per annum, but growth in per capita production was only 0.8%. Only CLSs 1a and 4 showed significant growth in per capita production. Milk density per sq. km of area was low in all the CLSs except CLS 5b in the hills and CLS 1b in the Terai region. Low milk density means scattered production and implies higher transaction costs in its collection and transportation.

Milk prices, both wholesale and retail, are fixed by the government through the Nepal Dairy Development Board. This has led to the inadequate growth of private diaries (Pokharel 2003). Such a control over prices acts as a deterrent to the growth of the dairy sector, as these prices do not reflect the true value of milk (Joshi and Bahadur 2002). The cost of milk production has been increasing due to increase in feed and labor costs, but these changes are not transmitted to milk pricing by the government. About 85% of the Dairy Development Corporation (DDC) processing capacity is located in the eastern and central development divisions (i.e., CLSs 1a, 2b, 4, 5b and 6). The western region accounts for 12% of the capacity (Joshi and Bahadur 2002). The present milk-processing capacity and skimmed milk powder (SMP) production capacity is not sufficient to process all the milk produced in the flush season leading to milk holidays (1–2 days in a week). In the lean season, the government is forced to import SMP to meet domestic demand for milk. The value of imports of SMP, whole milk powder (WMP) and condensed milk amounts to more than Rs. 1 billion a year, almost equal to the sale of fluid milk by the country's formal sector (Pokharel 2003). Seasonal imbalances and liberal imports are a major constraint to the growth of this sector (Devendra et al. 2000).

Table. 7.12. Total and per capita milk production and growth, Nepal, 1998.

System	Total milk production ('000 t)	Cow milk (%)	Buffalo milk (%)	Growth rate in milk production (%/annum)[1]	Per capita milk production (kg/annum)	Growth rate in per capita milk (%/annum)[1]	Cattle productivity (kg/animal) (1996-97)	Buffalo productivity (kg/animal) (1996-97)
1a	86.3	30.5	69.5	4.5	34.9	2.2	489.8	971.4
1b	98.6	34.3	65.7	4.8	42.4	1.4	355.5	921.4
2a	39.0	24.0	76.0	2.8	37.2	-0.1	491.0	921.9
2b	126.8	38.9	61.1	3.4	32.9	1.3	464.7	993.8
3	113.6	25.9	74.1	0.8	63.9	-0.6	293.0	746.6
4	50.3	47.9	52.1	4.3	67.7	2.2	430.7	746.1
5a	55.7	32.3	67.7	1.9	82.5	1.0	340.2	585.8
5b	53.5	30.0	70.0	2.5	31.1	-0.3	627.9	1019.4
6	305.3	23.4	76.6	-5.2	74.0	1.3	346.7	797.0
Mountain	84.0	38.9	61.1	1.7	56.3	0.7	319.9	707.8
All systems	**1,013.1**	**30.6**	**69.4**	**2.8**	**49.9**	**0.8**	**380.0**	**819.8**

1. Growth rate from 1986 to 1998.

The average milk yield of a cow is 380 kg/annum and that of a buffalo 820 kg/annum. All but CLS 1b in the Terai region have above average cow milk yields. In the hills, milk yield is relatively high in CLSs 4 and 5b. CLS 6 with the largest share in cattle population, has one of the lowest yields. Buffalo milk productivity is also above the national average in the Terai CLSs, and in CLS 5b in the hills. In fact, buffalo milk yield is the highest in CLS 5b and the lowest in CLS 5a. In the hills, many farmers keep animals for manure production even if they are unproductive in terms of meat and milk (Lawrence and Pearson 2002). It is the need for manure that integrates livestock closely with the farming system in the hill region (Thorne and Tanner 2002).

Buffalo meat is by far the most important meat with a share of 65% in total meat production, followed by goat meat (20%). Monogastrics account for 13%. Although buffalo meat production is dominant in most CLSs, meats of other species are also important in many of these. For example, in CLS 1b goat meat accounts for 30% of total meat production, in CLS 4 pork shares 16% and in CLS 5b chicken is also important (Table 7.13). Demand for non-ruminant meat has been rising due to fast growth in urbanization. The correlation coefficient between urbanization and chicken meat production is 0.90. It is high for other meats too, except goat meat.

Meat production increased significantly in most CLSs. Per capita production increased by 2% per annum (Table 7.14). Per capita egg production was highest in CLS 5b, followed by CLSs 1a, 6, 1b and 3. Per capita production, however, remained stagnant between 1991 and 1998.

Table 7.13. Share (%) of meat production by type in total meat production, Nepal, 1998.

System	Total meat production ('000 t)	Buffalo meat	Mutton	Goat meat	Pork	Chicken
		Share in total meat				
1a	15.3	67.6	0.1	22.1	3.2	6.7
1b	22.7	51.9	1.6	31.5	9.5	5.3
2a	5.6	68.8	0.4	22.6	3.3	4.5
2b	24.9	61.7	0.2	26.6	6.1	4.9
3	18.0	63.8	2.6	22.1	6.5	4.9
4	8.6	62.4	1.1	15.8	16.3	4.3
5a	8.0	81.1	0.1	17.3	0.4	1.3
5b	20.8	68.1	0.5	10.5	5.9	15.0
6	44.2	70.2	1.5	14.2	8.3	5.6
Mountain	15.9	62.8	7.5	17.8	7.3	4.6
All systems	**183.8**	**65.1**	**1.7**	**19.8**	**7.1**	**6.1**

7.3.1. Factors Influencing Productivity

There is a significant and positive relationship between milk yield of both cow and buffalo and feed availability from crop sources/livestock unit (Figures 7.1 and 7.2), indicating that feed is crucial to raising livestock productivity. Further, as expected feed availability is higher in CLSs having better irrigation facilities.

Table 7.14. Per capita meat production and growth, Nepal.

System	Per capita meat (kg/annum) 1998	Growth in per capita meat (% per annum) 1991-98	Egg production ('000 t) 1998	Per capita egg (no./annum) 1998	Growth in per capita egg (% per annum) 1991-98
1a	6.3	3.3	59.6	24.4	5.7
1b	8.5	3.1	49.3	18.6	-0.1
2a	5.0	-1.9	14.2	12.8	4.3
2b	5.9	2.7	56.0	13.1	0.3
3	10.0	1.3	31.6	17.4	-0.1
4	10.0	1.9	11.6	13.5	-2.0
5a	11.1	5.8	4.9	6.6	1.1
5b	11.6	3.3	96.9	54.1	0.5
6	10.2	2.3	92.5	21.4	-2.2
Mountain	10.2	0.8	28.0	18.0	-2.9
All systems	**8.5**	**2.3**	**444.5**	**20.6**	**0.1**

Apart from feed, improvements in infrastructure can lead to significant improvements in milk yield. The correlation between the milk yield of both cows and buffaloes and infrastructure (roads, veterinary institutions and dairy co-operatives) is positive. Milk yield is positively related with veterinary institutions, but unlike in India and Sri Lanka, the relationship is not statistically significant. Rainfall has no significant influence on milk yield. The correlation with urban population is also positive and significant, implying that productivity is higher in areas closer to urban centers (Table 7.15).

Table 7.15. Correlation between milk yield and selected variables in Nepal.

Variables/factors	Cow milk yield[1]	Buffalo milk yield[1]
Population density (no./sq. km of geographical area)	0.63	0.46
Urban population (%)	0.70	0.46
Road density (km/'000 sq. km of geog area)	0.68	0.44
Agricultural market density (no./'000 sq. km of geog area)	0.26	0.45
Dairy institutes (no./'000 livestock unit)	0.56	0.37
Veterinary institutes (no./'000 livestock unit)	0.34	0.15
AI centers (no./'000 livestock unit)	0.61	0.36
Feed availability (t/LSU)	0.61	0.61
Rainfall (mm)	0.06	-0.10

1. Yield of animals in milk (kg/animal/annum).

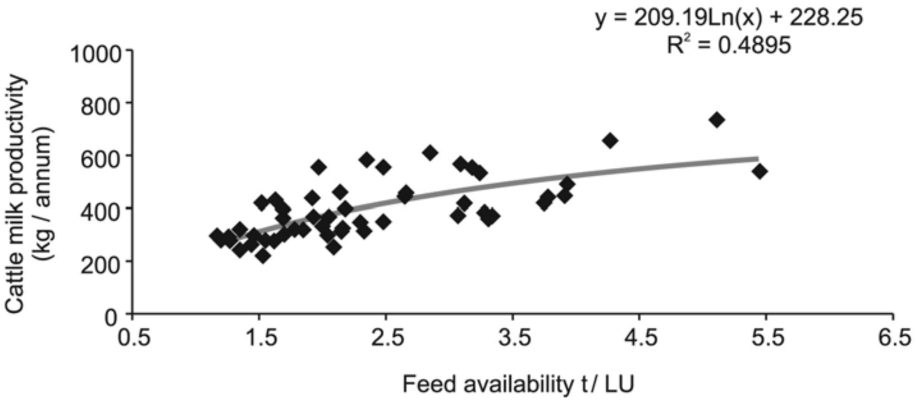


Figure 7.1. Relationship between district-level cattle milk productivity and feed availability in Nepal, 1998.

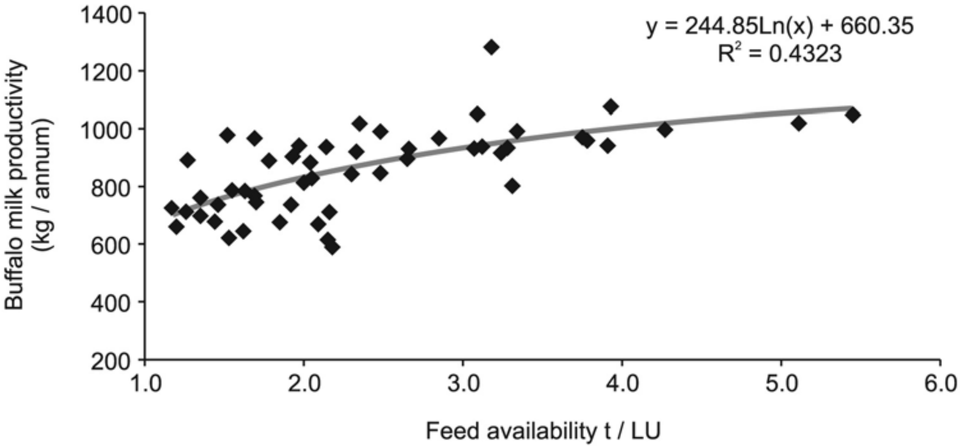


Figure 7.2. Relationship between district-level buffalo milk productivity and feed availability in Nepal, 1998.

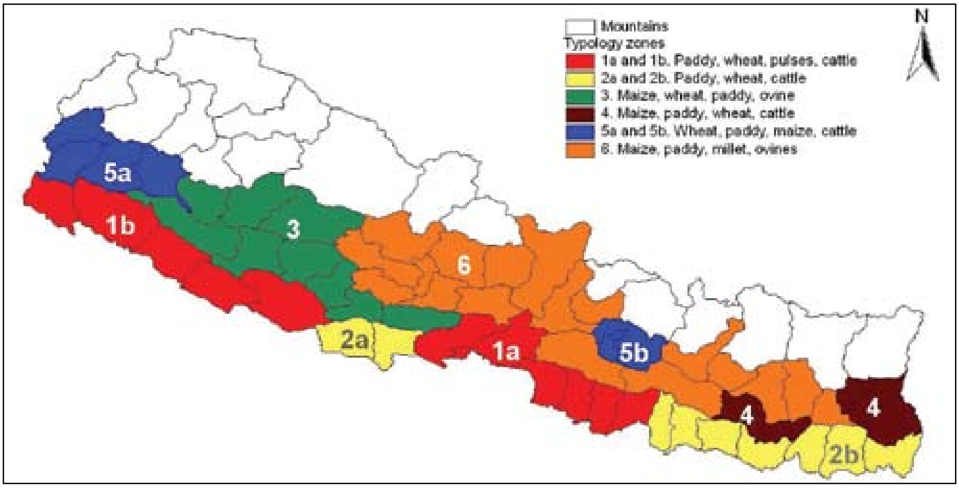
7.4. Strategies for Accelerating Growth

Researchers and policy makers emphasize the need to improve livestock production and productivity. In central, western, and mid-western regions, improved/crossbred buffalo raising was identified as the most promising technology to be promoted. In the eastern region, on the other hand, improved/crossbred cattle are considered more important. Next in importance are the technologies related to feed, such as more efficient utilization of crop residues. The other important technologies identified include improved/crossbred goat rearing and *ghee* making (in the mid-western region); improved pig raising and vaccination against diseases in commercial layers and broilers (in the eastern region); utilization of AIBPs (in the central region), and improved feed management in the last stage of pregnancy in cattle and buffaloes (in the western region).

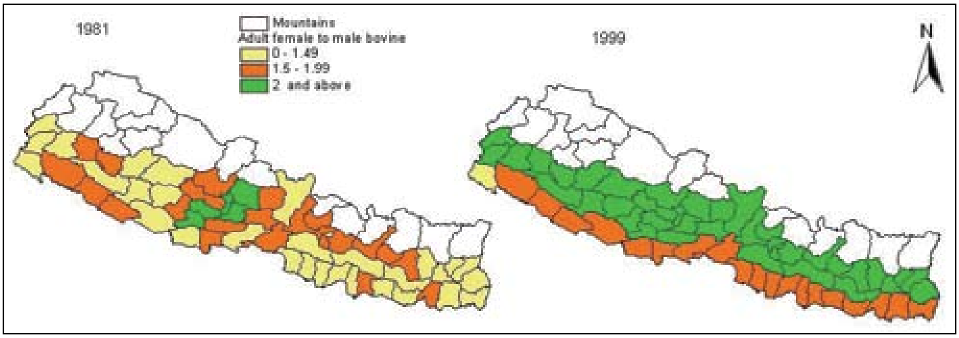
Milk pricing is another issue. There is a consensus of opinion that milk prices should be based on cost of production and be revised regularly. Currently, milk production is uneconomical, but farmers keep livestock to meet multiple requirements. Transporting milk to consumption/collection centers is another problem. In winters, narrow and unleveled motorable roads are used, but in late spring and rainy seasons, most milk is physically carried by human beings, taking 3–4 hours to reach chilling centers. The milk quality deteriorates and coagulation takes place because of high temperature and humidity. In such cases, popularizing the improved technology of making *ghee*, *butter*, *paneer* and *chhurpi* among farmers could avoid milk wastage. Short-term training in making milk products should be given to dairy farmers in milk-shed area.

Regarding fodder collection, there are government restrictions and there is no easy access to forests. Majority of the farmers depend solely upon cereal crop straw for 6–8 months to feed dairy animals. Suitable tree fodder saplings should be made available to farmers and forage crops should be introduced as relay crops between food crops. It is difficult for smallholder dairy farmers to produce forage crops for animals because they have limited land. Nevertheless, without affecting their main crops, some technologies/systems could be introduced for forage production in their farming systems. The following two systems could be introduced on a trial basis in farmers' fields -- quick-growing leguminous forage crops between widely-spaced rows of maize and forage crops grown during the fallow period in double cropping systems.

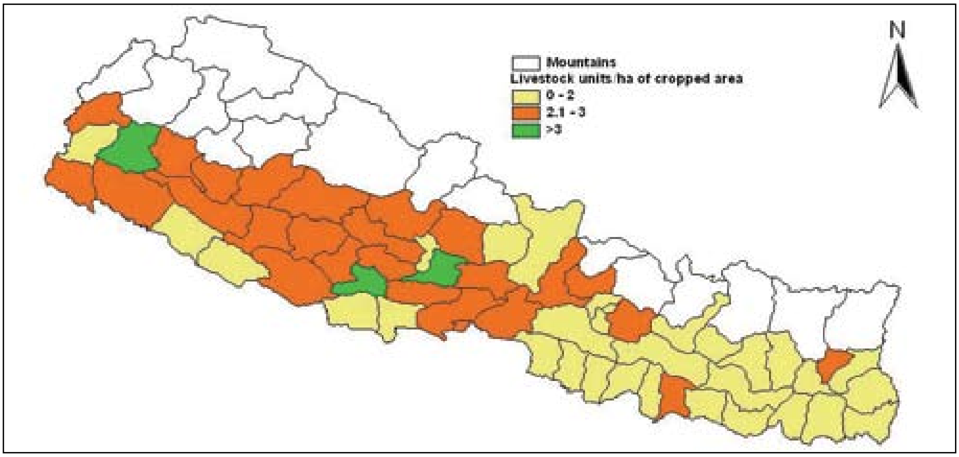
Since farmers rarely have good breeding bulls because of the high cost of maintenance, local bodies should be encouraged to maintain breeding bulls.



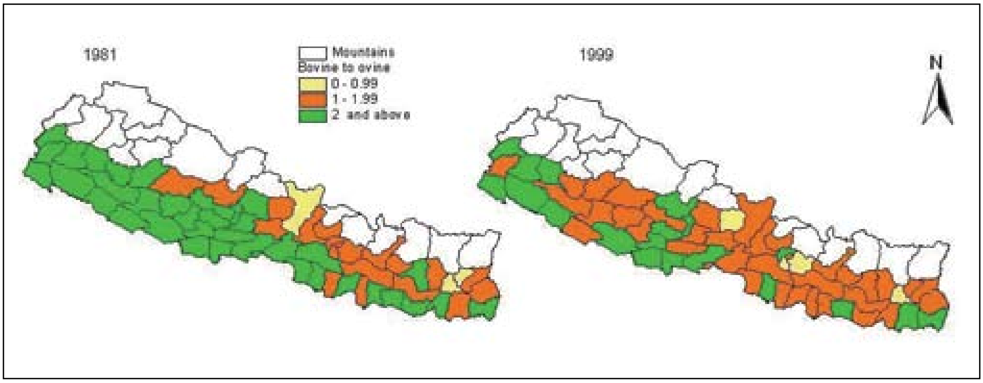
Map 7.1. Crop-Livestock Systems in Nepal, 1998.



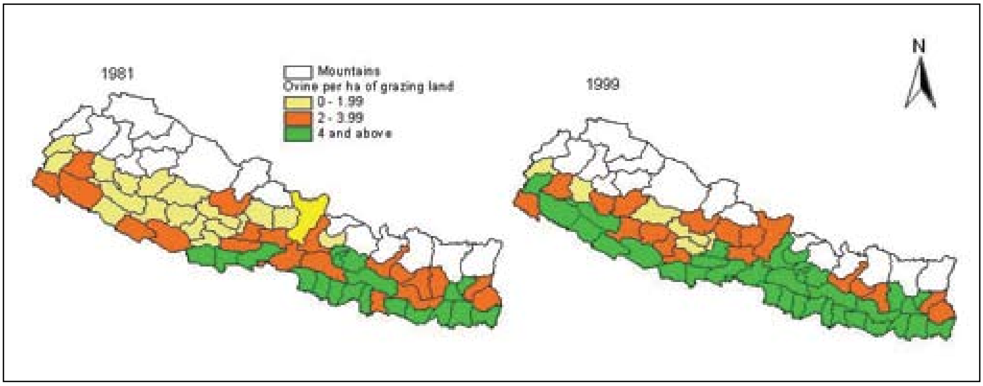
Map 7.2. Ratio of adult female bovines to male bovines in Nepal, 1981 and 1999.



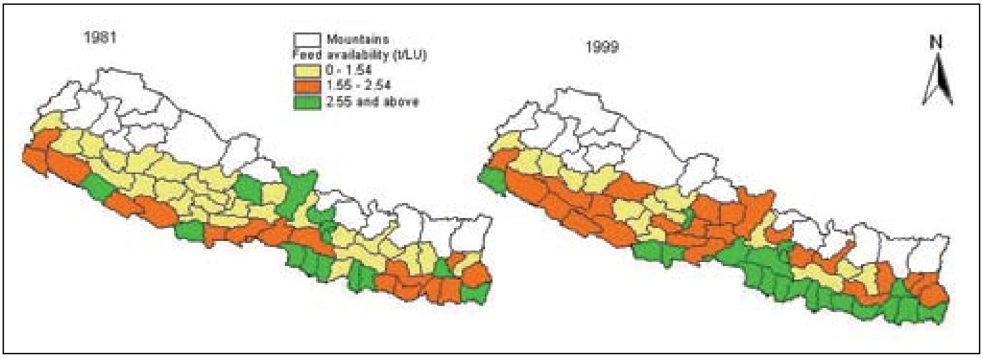
Map 7.3. Density of livestock units in Nepal, 1999.



Map 7.4. Ratio of bovines to ovines in Nepal, 1981 and 1999.



Map 7.5. Ovines per hectare of grazing land in Nepal, 1981 and 1999.



Map 7.6. Feed availability per livestock unit in Nepal, 1981 and 1999.

Appendix 7.1. Area under crops (%) relative to gross cropped area in Crop-Livestock Systems in Nepal, 1981 and 1998.

System	Paddy	Wheat	Coarse cereals	Maize	Millet	Barley	Pulses	Oilseeds	Sugarcane	Potato
					1998					
1a	43.1	19.2	11.0	10.3	0.6	0.1	13.8	7.2	3.9	1.9
1b	41.7	17.5	13.1	12.2	0.9	0.1	13.6	11.1	2.0	1.1
2a	65.9	20.9	1.3	1.1	0.1	0.1	3.9	3.4	3.2	1.5
2b	65.3	16.0	7.2	6.3	0.9	0.0	4.2	4.3	1.1	1.9
3	18.3	25.0	49.3	39.3	6.1	3.9	2.5	2.5	0.0	2.3
4	26.6	10.8	48.6	38.6	9.5	0.5	3.6	4.1	0.1	6.4
5a	25.9	34.1	30.1	19.7	7.9	2.4	5.1	2.4	0.2	2.4
5b	27.8	24.7	37.6	32.2	4.8	0.6	3.1	2.1	0.1	4.6
6	24.7	9.4	56.9	37.6	18.8	0.6	3.3	1.9	0.2	3.6
Mountain	18.1	17.7	50.6	27.4	18.3	4.8	3.5	1.0	0.0	9.2
All systems	**39.3**	**16.9**	**28.5**	**20.8**	**6.8**	**0.9**	**6.5**	**4.7**	**1.3**	**2.9**
					1981					
1a	55.7	18.3	11.7	9.4	1.8	0.5	11.0	0.3	3.0	NA[1]
1b	48.8	17.3	16.8	14.7	1.4	0.6	14.5	1.5	1.1	NA
2a	64.4	23.1	6.5	3.9	1.8	0.8	4.5	0.1	1.5	NA
2b	76.5	10.1	6.0	4.6	1.2	0.2	3.8	3.0	0.7	NA
3	19.3	22.7	45.9	31.9	10.2	3.8	3.8	8.3	0.1	NA
4	40.1	7.9	47.1	35.0	10.9	1.2	3.7	1.1	0.2	NA
5a	25.4	30.9	32.7	21.2	8.9	2.6	5.1	5.8	0.1	NA
5b	26.7	23.6	38.5	33.5	3.5	1.5	2.9	8.2	0.1	NA
6	28.9	10.3	48.0	38.8	8.1	1.0	4.3	8.4	0.3	NA
Mountain	17.7	11.4	49.9	28.5	19.0	2.4	3.4	17.6	0.0	NA
All systems	**49.1**	**15.3**	**23.8**	**18.1**	**4.7**	**1.0**	**6.6**	**4.4**	**1.0**	**NA**

1. NA = Data not available.

Chapter 8

Summary and Conclusions

Mixed farming of crops and livestock is the dominant form of agricultural production in South Asia. The two sectors are interlinked; the outputs of one are used as an input of another, and vice-versa. Such a synergy reduces production risks and uncertainty, stabilizes farmers' incomes and is environment friendly, thus ensuring sustainability of the farming system.

Poverty in rural South Asia is largely concentrated among the landless and small farmers who are in one way or another associated with Mixed Crop-Livestock Systems. Evidence from earlier studies indicates that agricultural growth in developing countries is more pro-poor, and livestock being an important component of the agricultural sector, it can make a significant contribution towards poverty reduction. Improving livestock productivity could thus serve as an important pathway to escape poverty as livestock resources in the region are more equitably distributed than land.

Mixed farming systems in South Asia have lately been under pressure to produce more to meet growing food demand. In particular, the demand for animal-based foods has been growing rapidly due to income growth, urbanization and changes in tastes and preferences, necessitating a corresponding increase in their supply. This is both an opportunity and a threat to the millions of smallholders subsisting on mixed systems. To ride the wave of growing demand for livestock products, small-scale farmers in mixed systems will have to remain competitive in the face of growing commercialization of crop and livestock sectors and the emergence of industrial livestock production systems where productivity levels are higher than those in mixed systems, albeit at huge environmental cost to the region.

Secondly, with liberalization, globalization and international trade under the WTO regime, it is feared that the flow of cheap imports from developed countries where the livestock sector is protected, may have detrimental effect on the livelihoods of millions of rural poor engaged in livestock activities in developing countries.

Until recently, most countries in the region were able to meet demand through domestic production. Growth in production largely came from an increase in animal numbers, with a small contribution from productivity. Productivity of livestock in South Asian countries is low, and the growth therein has been slow. Future growth will have to come from productivity improvements, as the number-driven increase in production is no longer feasible because of increasing pressure on natural resources. Productivity gains would translate to reduction in per unit cost of production, making the sector competitive both in the domestic and international markets.

Past attempts to increase livestock productivity have met with limited success since technologies were introduced without considering the close nexus between the crop and livestock sectors and in farming systems where preconditions (agro-climatic, socio-economic and infrastructure, etc.) for their success were not adequate. Since mixed farming systems are diverse in terms of crop and livestock activities and production conditions, and differ in their responses to development initiatives, technology uptake, market forces and policy, it is important to delineate them into homogeneous sub-systems with similar responses to external stimuli or interventions. Such a delineation would help in better targeting crop and livestock technologies and development initiatives targeted at small-scale livestock keepers.

This study has identified and characterized prevalent Crop-Livestock Systems in South Asia by following a systems approach that incorporates interactions between crop and livestock sub-systems and their underlying agro-ecological and socio-economic conditions.

8.1. A Synoptic View of Crop-Livestock Systems

Crop-Livestock Systems are heterogeneous in India, and a total of 18 systems have been identified. An important feature of these systems is their geographical contiguity. Paddy or wheat is the dominant activity in 50% of the systems. Sugarcane, groundnut, soybean and coarse cereals dominate in others. Dairying is an important activity in most systems. Cattle or buffalo dominate two systems, and are the second or third largest activity in others. Thus, livestock are an important source of livelihood for the rural people. Their share in agricultural income varies from 13% to 41% across systems, and has been growing faster in recent years compared to the crop sector.

Another important characteristic of mixed farming systems is their domination by smallholders. Average land and livestock holdings are small, but more so in highly populated systems in humid environments.

Livestock productivity is low, but varies across systems. Differences in productivity are mainly due to variations in feed availability, quality of animals and veterinary infrastructure. Feed availability (dry matter equivalent) ranges between

1 to 4 t/Livestock Units in India across CLSs. The proportion of high-yielding crossbreds in cattle population oscillates between less than 10% in some systems to over 50% in others. A similar variability has been observed in the adoption of improved poultry. Nonetheless, productivity is higher in systems better endowed with feed resources and animal health and breeding services. Further, rural poverty is negatively associated with livestock productivity, implying that improving productivity of Crop-Livestock Systems would enable smallholders to escape poverty.

Mixed farming is the norm in Nepal, and as many as nine Crop-Livestock Systems have been identified there. Paddy is the dominant agricultural activity in the irrigated systems spread over the plains i.e., Terai region. Cattle and buffaloes are important species there. In the hill-based CLSs, coarse cereals/wheat are important crops, and cattle and small ruminants are important livestock species.

Livestock contribute about a third of the country's agricultural income. However, the kind of livestock revolution observed elsewhere in South Asia has not occurred in Nepal, mainly due to a lack of income growth and low level of urbanization. Here, the crop sector has grown faster, implying that achieving foodgrain security is still a major concern.

Livestock productivity in Nepal is one of the lowest in South Asia due to a lack of sufficient feed and fodder, poor quality of animals and underdeveloped animal breeding/health services, markets and roads. Nevertheless, there are inter-system differences in productivity within the country. It is higher in the systems located in the Terai region having better feed and fodder availability, higher adoption of improved breeds of cattle and buffalo and a better network of veterinary and other infrastructure. Higher income and urban population -- major drivers of demand growth -- are the incentives to invest in productivity-enhancing technologies and practices. On the other hand, livestock production systems in the hill region are severely constrained by supply-side factors i.e., insufficient feed and lack of access to markets and roads. Common lands and forests that are an important source of feed are under pressure due to increasing human and livestock populations. However, in hill locations closer to demand centers, commercialization of dairy production is taking place.

Since an overwhelming majority of the population in Nepal is rural with high incidence of poverty, improving livestock productivity, which is an important source of livelihood, would help many poor escape poverty.

In Sri Lanka, as in India and Nepal, mixed farming is the dominant form of agricultural production. Livestock contributes 14% to agricultural income and about 35% of farm households are associated with livestock production.

The clustering of agricultural activities yielded six CLSs for Sri Lanka. Paddy is a dominant activity in two of the systems falling in the low country dry and wet agro-ecologies. Plantation in three systems in the up, and mid country agro-ecology, and fruits and vegetables in one system in the low country dry agro-ecology emerged as the other dominant activities. In fact, growing fruits and vegetables are the second most important activity in most CLSs in the country.

Livestock, especially cattle, are important throughout the country. Buffalo is also becoming an important milch species in peri-urban dairying. Goat rearing is practiced on a large scale in the low-country CLSs. Cattle and buffaloes are largely of the indigenous type in most systems, except in the mid- and up country estate-based systems where crossbred cattle are important. Low-producing animals are often left to graze in harvested paddy fields and are moved to scrub land in the crop season.

Milk yield is very low in CLSs in the dry regions. It is higher in systems having a higher population of exotic and crossbred cows, better roads and markets and veterinary infrastructure. Dairy production in the country is under stress. Milk production is almost stagnant, and the country depends on imports to meet growing domestic demand. Productivity of meat animals in Sri Lanka, especially pigs and goats, is the highest in the region.

8.2. Improving Livestock Productivity

8.2.1. Technology and Management Interventions

Feed and nutrition: Feed scarcity is a major limitation to improving livestock productivity in South Asia. The magnitude of the problem varies across CLSs. It is acute in the rainfed-based CLSs where opportunities for growing food-feed crops and forages in the post-rainy season are limited. The productivity of common grazing lands is also poor in these environments. Thus, the seasonality in feed-fodder availability acts as a disincentive to maintain quality animals.

Options to mitigate feed scarcity include storage of crop residues, especially cereal straws, to overcome fodder scarcity in the dry period, growing multi-utility tree species as part of agro-forestry and enhancing the productivity of common grazing lands through technological interventions and better management and participatory approaches. Another option would involve developing fodder markets by promoting inter-regional trade in roughages. Irrigated regions have a surplus in wheat and rice straw that can be transported to scarce regions. This is, however, a costly proposition since roughage is bulky and involves substantial transportation costs. Transportation of straw/fodder in compressed forms can be explored to reduce transportation costs.

In the CLSs under the semi-arid tropics, cereal crop residues form the bulk of feed. With expansion of irrigation in several systems in this region, paddy and wheat straw availability has increased, while availability of stover from coarse cereals has stagnated or declined putting pressure on their price. Farmers in recent years are growing coarse cereals (sorghum and pearl millet, etc) mainly for their fodder value; hence improving the quantity and quality of straw through breeding of dual-purpose crop varieties with better digestibility coefficient, disease resistance, etc., will to some extent help mitigate their shortfall. At the same time, it is necessary to improve the cost-effectiveness of existing nutritional and supplementation technologies. A number of simple technologies such as chaffing of straw and fodder, and wetting, soaking, grinding and pelleting of feed grains should be promoted to increase feed intake and reduce wastage.

Paddy straw is an important fodder for livestock in most CLSs in the humid environment. Its quality is however poor. Animal nutrition research has generated technologies such as urea/molasses treatment that improve palatability and digestibility of paddy straw. However, their adoption at the field level is poor throughout South Asia due to their high labor requirement and the lack of demonstrable economic returns. Such technologies have fair chances of success in labor-abundant CLSs. Another technology introduced in Sri Lanka was to provide all the nutrient requirements together through UMMB. As the demand for UMMB is picking up, some commercial establishments and farmer oganizations in Uva and the Southern province have expressed interest in manufacturing it. Policies to encourage this industry need to be formulated.

In the arid and hill systems, the availability of common lands/pastures is better compared to intensively cultivated irrigated regions. In fact, common lands contribute a substantial share in total feed supply. Their productivity, however, is poor, due to excess grazing and lack of proper management. Since grasses and shrubs from CPRs are the main source of feed, policy changes should be aimed at improving access to and rights of the poor to use CPRs. Community decision making and village-level participation in the upkeep of CPRs should be promoted by enabling local bodies and non-government organizations (NGOs), and if needed, the government should assist them through financial, technical and legal backstopping.

Green fodder cultivation in most countries in the region is limited to a very small fraction of land. The land holdings are extremely small and there is intense competition for land between food and forage crops. Countries like Nepal and Bangladesh are yet to attain food self-sufficiency; so food production gets preference over forage production.

Hence, there is a need to evolve crop-farming systems that involve minimum trade-off between food and feed security. Introducing forage crops as sequential crops between two food crops is an option. However, this is constrained by a lack of short-duration fodder varieties suitable for different production environments. Therefore, breeding programs should not only focus on developing high-yielding and high-quality fodder and forage varieties suited to varying farming situations, but also experiment with short-duration fodder crops that can be grown without compromising food production. Additionally, even where improved cultivars are available, fodder seed production, its multiplication and distribution systems in most countries need to be strengthened.

Use of grain and AIBPs is extremely low in South Asian countries and their feeding is restricted to improved breeds and mainly in better endowed CLSs with high agricultural productivity and those closer to the demand centers. The alternatives to increasing domestic production of concentrate feed include raising productivity of cereals, pulses and oilseeds and increasing the area and productivity of sorghum, maize, pearl millet, etc., whose grains are an important source of animal feed. The use of non-conventional feed resources like seed cakes of mahua (*Madhuca latifolia*) and neem (*Azadirachta indica*) can also be explored.

Genetic enhancement: Most livestock species in South Asia are of indigenous type with low genetic potential. Indigenous species can produce the required amount of food, but through the number-driven route, which is undesirable because of land constraints. Crossbreeding of indigenous species with high-producing exotic ones is an important strategy to increase livestock productivity. In most South Asian countries, attempts to promote crossbreeding in ruminants have met with limited success because of unfavorable production conditions, the most crucial one being the non-adaptability of crossbreds to tropical climatic conditions. Further, crossbreds require better health care and quality nutrition, while animal health delivery systems in most livestock production systems are underdeveloped.

Breeding services are also inadequate, and the success rate of artificial insemination hardly exceeds 25%. Finally, though crossbred cows are high yielding in milk, their males are not a good source of draft power. But in mixed farming systems where the use of mechanical power is increasing, crossbreds are increasingly replacing indigenous cattle as has happened in the Indian states of Punjab and Haryana. In the context of crossbreeding in cows, the Indian experience suggests that introducing crossbreds in subsistence-oriented livestock production systems without considering their climatic adaptability, health and feed requirements, and socio-economic conditions has limited chances of success.

Buffaloes are an alternative to crossbred cows because of their adaptability to varied climates and better feed conversion efficiency compared to indigenous cows. They are found everywhere in South Asia, but with significant specialization of breeds in different systems, especially in India. Genetic research and development programs should focus on upgrading native breeds of buffalo.

Small ruminants are important for the livelihood of the poor, especially in marginal environments. Their low and stagnating productivity in most CLSs needs to be increased. In the short run, better feed and health care will contribute towards improving their productivity; improvements in the long run will have to be driven by genetic research.

Animal health: The genetic potential of livestock cannot be realized unless they are protected against diseases. Animal health infrastructure and manpower have grown substantially in South Asia, especially in India, but a number of deadly diseases such Foot and Mouth Disease, Brucellosis, PPR, Avian influenza, hemorrhagic septicemia, black quarter, etc., haunt livestock frequently. These cause substantial losses to livestock production. Birthal and Jha (2005) report an annual loss of Rs 52 billion in dairy output in India due to diseases. The losses are higher in the high-rainfall low-irrigation and low-rainfall low-irrigation CLSs, where incidentally, livestock yields are low and veterinary infrastructure is poor. In countries such as Nepal, animal health infrastructure and manpower are far from adequate, more so in the hills.

Animal health services are in the domain of the public sector and subsidized, but are plagued with inefficiency. Further, the focus of public veterinary services is largely on curative treatment, ignoring preventive control. Currently, there is an intense debate going on about the role of the public and private sectors in providing health services. It is argued that the public sector should focus on services that are of public goods in nature, and the rest should gradually be transferred to the private sector. On the contrary, it is also disputed that withdrawal of the public sector might adversely affect the poor. Evidence however shows that the poor are willing to pay for veterinary services if these are efficient and available on time (Ahuja et al. 2000).

Intensification of livestock production is invariably accompanied by increased disease risks. A weak veterinary infrastructure will restrict production and market opportunities. Social science research has shown that investment in animal health research in less-favored livestock production systems can bring about significant improvements in animal productivity and thereby farmers' incomes (Kristjansen et al. 1999).

In general, animal science research in Crop-Livestock Systems with a high incidence of poverty and low resource endowment (irrigation, improved seeds, etc.) should focus on research strategies that are less capital intensive, have a higher probability of success, are well accepted by the clientele and yield a good rate of return. Animal nutrition and health fall in this category. In the long run, genetic research holds the key to growth and development of the livestock sector.

8.2.2 Markets and Institutions

Markets and institutions stimulate growth by facilitating exchange of goods and services. Thus, easy access to markets and/or institutions is an important precondition to improving livestock productivity. Income from participation in markets is an important incentive for producers to improve the scale and productivity of livestock. This is evident from the positive association between livestock productivity, road density and urbanization in India and Nepal. Nevertheless, markets for livestock and livestock products are underdeveloped and dominated by the informal sector in most South Asian countries. The informal markets play an important role by providing an opportunity for small-scale producers to participate in the market despite their small surpluses. However, non-participation in more formal markets discourages smallholders from using improved technologies and quality inputs.

There are also apprehensions that with the on-going livestock revolution in developing countries, smallholders may be displaced by large commercial producers in most CLSs due to lack of economies of scale in production and and high marketing and transaction costs. For example, poultry production in much of South Asia is becoming industrialized to the neglect of backyard poultry. Also, dairy and small ruminant production are increasingly commercialized close to demand centers, thereby adversely affecting the competitiveness of smallholders in remote areas.

The question often raised is whether sustaining the livestock revolution is compatible with sustaining small-scale livestock producers? This is because the demand-led livestock revolution is accompanied by the emergence of supermarkets and export markets that alter the way in which meat and dairy products are assembled, inspected, processed, packaged and supplied to consumers. Competitive prices and product quality would dictate demand. Thus, it is important to take measures that would enable small holders to continue to participate in the more modern agri-food value chains (Coasteles et al. 2006). While changes in the structure of markets is inevitable, in South Asia, informal markets will continue to be important for many more years to come. Hence measures to strengthen this sector and bring it into the mainstream marketing system would enable small-scale producer participation in the livestock revolution.

At the same time, to enable smallholders to benefit from the demand-led livestock revolution, there is a need for a pro-poor livestock policy and appropriate institutional formats that integrate them into modern supply chains. Co-operatives, producers' associations and contract farming are important means of improving access to markets. In India, dairy co-operatives have played an important role in this aspect. Contract farming is emerging as an important link between producers and markets, especially in poultry. Such institutional arrangements improve producers' access to credit, technology, inputs, information, extension services and risk-mitigating mechanisms. Birthal et al. (2005) have shown that contract farming in milk production has helped producers improve productivity, scale-up production and reduce marketing costs. Organizing farmers into groups or associations to improve their bargaining power vis-a-vis large processing industries is an option that should be pursued by vigorously implementing policies that encourage formation of such groups (Bennett et al. 2006).

Two other institutional aspects that have a direct bearing on the scale and productivity of livestock are credit and insurance. Lack of capital and higher production risks are important barriers to the expansion of smallholder livestock production. At present, credit and insurance support to livestock production is meager (Birthal and Taneja 2006). Policy interventions are thus needed to improve credit flow to the livestock sector and strengthen insurance support, especially to poor smallholders.

Food safety and quality standards/regulations are becoming stringent in global as well as domestic markets, and their compliance by stakeholders in the supply chain is critical to the growth of the livestock sector. This calls for preparing livestock producers and other stakeholders to quality-driven markets. Additionally, in remote areas, value addition at the village level would help improve the marketability of perishable products. For example, in Nepal, there is a need to look into government policies related to milk pricing and procurement. To enable farmers to use surplus milk effectively, production of milk products with longer shelf life through improved and cost-effective methods should be promoted.

Policy makers and development agencies should implement programs related to the livestock sector to raise productivity while taking stock of the future challenges. For instance, as the livestock revolution progresses, we can expect a greater concentration of livestock production close to demand centers i.e., urban/ peri-urban areas, owing to the perishability of the products. This may undermine the participation of small-scale producers in the hinterlands. Hence, steps need to be taken to provide infrastructure like modern cold chains for speedier and safe transportation of produce from rural areas to more distant markets. Secondly, policies need to be in place to reduce the intensification of livestock production close to urban centers by taxing industrial systems for environmental pollution while at the same time providing incentives for processing and distribution chains to locate and spread out in rural areas. These would, in turn, be linked to the production areas on the one hand and demand centers on the other. Land and livestock balances have to be achieved on a areawide framework.

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The National Centre for Agricultural and Policy Research (NCAP) was established by the Indian Council of Agricultural Research (ICAR) with a view to upgrade agricultural economics research through the integration of economics input in the planning, design, and evaluation of agricultural research programs, and to strengthen the compentence in agricultural policy analysis within the Council. The Centre is assigned a leadership role in this area, not only for various ICAR institutions, but also for the State Agricultural Universities. In order to make agricultural research a more effective instrument for agricultural and rural change and to strengthen policy-making and planning machinery, NCAP undertakes and sponsors reserach in agricultural economics relating to problems of regional and national importance.

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The CGIAR Systemwide Livestock Programme (SLP, http://www.vslp.org/vslp/) is a consortium of 11 CGIAR centres (CIAT, CIP, CIMMYT, ICARDA, World Agroforestry Centre/ICRAF, ICRISAT, IFPRI, IITA, ILRI, IRRI and IWMI) and their partners. The SLP conduct research that helps people who live in regions with high levels of rural poverty. Focusing on small-scale crop-livestock producers, the Programme exploits synergies in the CGIAR and development systems to look at food-feed crops as a key entry point for improving the productivity and sustainability of smallholder mixed farming systems.

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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