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Increasing animal productivity on small mixed farms in South Asia: a systems perspective

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Abstract

Smallholder crop–animal systems predominate in south Asia, and most of the projected future demands for ruminant meat and milk are expected to be met from the improved productivity of livestock in these mixed farming systems. Despite their importance in the sub-region, there is a paucity of information on research that incorporates animals interactively with cropping. Livestock research has tended to highlight component technologies, often treating diverse and complex mixed farming operations as a single system. Furthermore, little attention has been paid to social, economic or policy issues. Thus, many of the technological interventions have either failed to become adopted at farm level or their uptake has proved unsustainable. This paper reviews aspects of animal production in South Asia; the trends and forecasts for animal populations and products, constraints to productivity, research opportunities and some key examples of technologies that have failed to achieve their full potential on farm. A systems analysis of small-scale crop–livestock operations is advocated, as a precursor for targeting appropriate interventions at farm level to increase animal productivity and protect the natural resources base.

Keywords: South Asia; Mixed farming systems; Livestock; Productivity; Systems analysis

1. Introduction

Mixed farming systems, in which crops and animals are integrated on the same farm, cover some 2.5 billion ha of land globally (De Haan et al., 1997). These

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farming systems produce 92% of the global milk supply, all of the buffalo meat and approximately 70% of small ruminant meat. About one-half of the total milk and meat produced comes from the developing countries. Mixed farming systems are probably the most benign from the environmental perspective because they are, at least partially, closed systems. The waste products (crop residues) of one enterprise (crop production) can be used by another enterprise (animal production), which returns its own waste (manure) back to the first enterprise. As a way of diversifying the sources of income and employment for resource-poor farmers, mixed farming offers considerable potential for poverty alleviation in rural areas. Since women play an important role in animal production, the development of this sub-sector is also of relevance to the promotion of gender equity. There can be little doubt that small-scale mixed farming systems will continue to play a pivotal role in animal production in developing countries in the foreseeable future. These systems are widespread in all agro-ecological zones in developing countries, from the lowlands to the highlands, and occur under different climatic and edaphic conditions. Six of the 11 global production systems, with which livestock are associated, are classified by Sere and Steinfeld (1996) as mixed crop–animal systems.

Thomas (1999) has described the characteristics of small-scale mixed farming systems. A major feature is the great diversity and complexity in the crops grown, the cropping patterns used and the livestock species raised. Annual and perennial crops are produced, including tree species, and ruminants, non-ruminants and aquaculture are integrated into these systems. Although cereals are usually the major crops produced, a wide range of other crops (roots, tubers, legumes, oilseeds, fibres, and sugarcane) are also grown. The main tree crops associated with mixed farming systems are coconut, oil palm, rubber and various fruits. Both single and multiple cropping systems are common. In many cases rotations are practiced. Thus, mixed farming systems produce a range of agricultural crops, whose residues and by-products are of importance in animal nutrition.

In South Asia, small-scale mixed farming systems are the dominant production units (Vaidyanathan, 1998; Devendra et al., 2000). For centuries, the use of large ruminants for cultivation has been almost universal, whilst non-working animals were maintained as a source of milk, manure and calves. Most dairy animals were owned by crop cultivators in the rural areas, and fed mainly on crop residues and by-products. The bulk of the milk was sold to the urban population. Nomadic groups played a more important role in the case of small ruminants, but sedentary rural households (both cultivators and non-cultivators) still carried most of the animals. These features continue to be a characteristic of small-scale farming in South Asia. A very large proportion of poor people still depend on livestock, which not only provide a means of security and survival, but also supply vital dietary animal proteins and a cash income. The latter is generated through the sale of milk, animals for slaughter or through the supply of live animals to more intensive systems in peri-urban and urban areas. However, the role of livestock in small-scale mixed farming systems goes well beyond the production of commodities such as meat and milk (Thomas, 1999). Animals are also important for the maintenance of soil fertility and the sustainability of the cropping systems.

Draught power is essential for early land preparation and for soil conservation purposes; manure is produced as a source of organic matter to improve soil physical conditions and nutrients for crop growth. The dependence of people on livestock cannot be over-emphasised. Approximately 49% of the population in the sub-region is below the poverty line (World Bank, 1993), and there is a very high percentage of rural poor as a percentage of the total poor; in India this is about 79%. Currently, production and consumption levels of animal products are low. However, in the future, rising human populations, higher incomes, urbanisation and changing consumer preferences will fuel increased demands for these products (Vercoe et al., 1997).

Most of the projected increases in demand for ruminant meat and milk in the sub-region are expected to come from the improved productivity of animals in the small-scale mixed farming systems (Devendra et al., 2000). This will require the removal of technical, social and economic constraints through research and technology transfer with appropriate policy support. Major opportunities exist to increase livestock productivity in the mixed farming systems of South Asia and to make more efficient use of key farm resources. However, despite the importance of these systems, Devendra et al. (2000) reported a paucity of information on research that incorporates animals interactively with cropping. 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. Additionally, livestock research has tended to highlight component technologies and neglect social, economic and policy issues. Interventions have been applied widely, treating complex and diverse crop–livestock systems as a single production unit.

The purpose of this paper is to review aspects of animal production in South Asia; the trends and forecasts for animal populations and products, constraints to animal productivity, research opportunities and some key examples of those technologies that have failed to be adopted at farm level to any significant extent. A need to undertake a systems analysis of small-scale crop–livestock operations is advocated, to improve the relevance and effectiveness of the interventions at farm level aimed at increasing animal production and protecting the natural resources base.

2. Livestock and their products: trends and projections

In 1996, South Asia had 1.2 billion people, representing 22% of the global population (Devendra et al., 2000). This has been projected to increase up to 1.7 billion by 2010. In all of the countries, agriculture is a major activity contributing 25–43% to Gross Domestic Product (GDP), whilst livestock (excluding manure and draught power) contribute 10–45% to the agricultural GDP. In the national agricultural policies, crop enterprises (particularly high-input rice and wheat production) have been highlighted in order to meet the grain needs of the rapidly increasing population. Irrigated cropping systems have been developed in high potential areas but, with the exception of Pakistan and Sri Lanka, the countries remain significantly dependent on rain-fed agriculture.

The pattern of livestock numbers and production reflects cultural, economic and environmental differences. The sub-region has large and diverse livestock populations that represent 19 and 69%, respectively, of the world cattle and buffalo numbers. The corresponding figures for goats and sheep are 30 and 7%, respectively. Projections to 2010 indicate that the buffalo population will increase faster than the cattle population, particularly in India and Pakistan, where they are important producers of milk (Vercoe et al., 1997). The numbers of small ruminants are growing at a higher rate than large ruminants, with the goat population expected to grow faster than that of sheep. The bulk of the Asian small ruminant population is found in the South Asia sub-region, notably in India and Pakistan, with a small but significant number in Bangladesh. The exception to this trend is Sri Lanka, where the populations of both large and small ruminants are declining. The reasons for this are obscure. The poultry population is expected to increase 1.5 times by 2010, with growth rates higher than those for pigs.

Despite the large numbers of animals in the sub-region, livestock production is low. Beef and veal yields are about 65% of the developing world average, whilst milk, mutton and lamb yields are about the same as the developing world average (FAO, 1996). Meat production is dominated by small-scale systems, and is derived from a number of different livestock species. For example, in Bangladesh, India and Sri Lanka, beef and veal contribute 32.4–43.1% to meat production (Vercoe et al., 1997). On the other hand, in Pakistan, buffalo meat (27.7%) and goat meat (26.7%) are the major contributors to production.

Ruminant meat consumption dominates total meat consumption in South Asia, whereas the reverse is true for the countries of Southeast Asia (Vercoe et al., 1997). However, at the present time, the human consumption of animal products is low (Delgado et al., 1999). The per capita consumption of meat in India and the rest of South Asia is only 4.0 and 7.0 kg, respectively. This compares with a mean of 21 kg for the developing world and 76 kg for the developed world. Per capita milk consumption in South Asia is 58 kg, slightly higher than the developing country average of 40 kg, but still appreciably lower than the developed world mean of 192 kg. The highest per capita milk production is in Pakistan (130 kg), followed by India (70 kg), Bangladesh and Sri Lanka (both <20 kg). However, as mentioned previously, the demand for milk and meat will increase in the future, as a result of economic development. For example, ruminant meat demand (kilogram per capita) in the different countries of the sub-region will increase from a range of 2.1 (Sri Lanka) to 12.7 (Pakistan) in 2000 to 2.7–20.3 in 2010 (Vercoe et al., 1997). The same authors projected that India, Pakistan, and possibly Bangladesh, will be self-sufficient in milk by 2010. In all countries, except Bangladesh and Bhutan, there is a major shift in milk production from the cow to the buffalo. Countries such as India, that are currently net exporters of ruminant meat, will drift back to self-sufficiency. It is likely that much of the increased overall demand for meat will be met by the increase in poultry numbers. Although India is projected to be self-sufficient for non-ruminant meat, Pakistan is forecast to be a significant net importer of this commodity by 2010. However, these projections could become distorted by the political environment and policy decisions.

3. Meeting increased demands for animal products

Some of the deficits in production of livestock products in the sub-region will be satisfied by imports. Nevertheless, a substantial proportion of the projected increases will be achieved by each country from within its existing sources, i.e. mainly the small-scale crop–livestock farming systems. In terms of production and the livestock numbers they support, it is the mixed rain-fed and irrigated systems, mainly in the arid and semi-arid tropics and sub-tropics that are the most relevant. Humid agro-ecological zones in South Asia are relatively small compared with those in Southeast Asia. The grassland-based systems, usually involving transhumance, are important only in relatively small areas of Bhutan, India, Nepal and Pakistan. They carry a very small proportion of the livestock population, and do not offer significant opportunities for improvement. Thus, they have a negligible capacity to contribute to future demands for animal protein (Vercoe et al., 1997).

During recent decades, there have been significant changes in the populations of ruminants within the small-scale mixed farming systems of South Asia, related to the value of animals for milk, meat or work and the size of holdings (Vaidyanathan, 1998). Data for Bangladesh and India show that the landless and those with little land (<0.2 ha) keep few ruminants per household. Thereafter, the numbers of large ruminants per household increase with the size of holding. Smaller holdings carry more small ruminants and fewer adult male large ruminants but, as the size of the holding increases, this situation is reversed. For example, in India, on farms above about 3 ha, more females (dairy animals) are kept than males (draught animals) and more buffalo than cows. These changes are related to the availability of crop residues and by-products; the larger farms producing more feed resources able to support increased numbers of large ruminants and dairy animals with higher nutrient demands. However, there are marked regional variations within the different countries. The trends indicate the increasing importance of dairy production and, to a lesser extent, meat production at the expense of draught power; and the replacement of the cow by the buffalo as the main dairy animal in large parts of South Asia. Furthermore, the greater availability of artificial fertilisers is reducing the use of animal excreta for supplying plant nutrients (Vaidyanathan, 1998). This has major implications for the sustainability of cropping systems. On the Indo-Gangetic Plain, for example, the productivity of the rice–wheat systems is threatened because of the decline in soil organic matter content. The factors contributing to these overall changes include the growing human population pressures on arable land; the mechanisation of cultivation and rural transport; the increasing availability of crop residues and by-products; the growing market for meat and milk; and government interventions to promote animal production (Vaidyanathan, 1998). However, little is known about the relative contribution of these factors to the important regional variations that occur in draught animal densities; the ratios of work to milk animals, dairy cows to milk buffalo, large to small ruminants; and the extent of rain-fed to irrigated agriculture.

4. Constraints to animal production

If mixed farming systems are to provide much of the projected increases in the availability of animal products, then technical, social and economic constraints have to be removed through research and technology transfer with appropriate policy support.

4.1. Animal genetic resources

Genotypes are both a constraint and a benefit to improved productivity, particularly in the rural-based small-scale production systems (Vercoe et al., 1997). Animal genetic resources in the sub-region reflect the considerable population size and the biodiversity that exists within given species. The breeds of the sub-region constitute a high proportion of the total number of breeds in the whole of Asia. Buffalo, cattle, goats and sheep account for approximately 74, 62, 56 and 23%, respectively, of the total populations in Asia (Devendra et al., 2000). These breeds are distributed across all of the agro-ecological zones from the arid/semi-arid areas of India and Pakistan, through the high altitudes of the Himalayan region (Bhutan, northern India/Pakistan, and Nepal), to the humid zones of Bangladesh, southern India and Sri Lanka. Although the indigenous genotypes have resistance to the environmental stresses that operate in the sub-region, many of them have not been described or characterised adequately in terms of these valuable genetic traits. Important cattle breeds include the Gir, Ongole (Nellore), Red Sindhi and Sahiwal; those of buffalo, the Jaffarabadi, Murrah, Nili-Ravi and Surti; those of sheep, the Chokla, Ganjam, Magra and Muzzfarnagri; and those of goats the Barbari, Black Bengal, Jamnapari and Sirohi. Valuable indigenous breeds also exist for the camel, mithun, yak and poultry. However, the productivity of indigenous breeds is often low and is further compromised by poor nutrition and problems of disease. In order to achieve rapid increases in, for example milk yield, local stock has been crossed with exotic breeds. The implications of this strategy will be discussed later.

4.2. Feed resources

The greatest challenge confronting the livestock systems of Asia is to increase the availability of animal feeds, both in terms of quantity and quality (particularly protein content). According to Vercoe et al. (1997) there are two components to this: the first is to improve the seasonal and annual supply of nutrients, and the second is to reduce the competition for available feeds. The second component involves a reduction in the numbers of animals that are being kept on maintenance or near maintenance rations, so that the remainder can be fed at higher levels. This will rely largely on government policy and incentives to increase markets and encourage the early sale of animals.

The feed resources of South Asia have been reviewed in Renard (1997), and include native grasses, weeds, crop residues, crop by-products, cultivated forage crops and tree foliage. In the small-scale mixed farming systems, particularly those with intensive cropping, the proportion contributed to diets by cultivated forages is relatively small. In these systems, crop residues are becoming increasingly important. The principal residues used are the straws of cereals and pulses. Equally important are the by-products of oilseed processing, grain milling and other agro-industrial activities. However, these tend to become available in the urban and peri-urban centres, not in the rural areas, and are more associated with specialised non-ruminant systems. Agro-industrial by-products and non-conventional feed resources contribute <10% to ruminant feed.

In Bangladesh, crop residues contribute 70% to animal feed, and are derived mainly from rice, wheat and pulses (Maehl, 1997). Rice straw and bran contribute 90% of the energy available for ruminants. However, only 40% of the straw produced is used for livestock feed, due to alternative uses and losses in storage. In India, Singh et al. (1997) report that some 350 million tonnes of crop residues are available, constituting 66% of the required feed supply. However, this estimate probably assumes that crop residues are available solely for animal feed when, in practice, they are not. For example, in some areas of the Indo-Gangetic Plain in the state of Punjab, 80% of rice straw and 40% of wheat straw are burned (Sidhu, 1996). In Nepal, cereal straws contribute 51% to the available feed resources. In Pakistan, some 40 million tonnes of crop residues are produced annually, and crop residues constitute 46% of the total feed resources. Rice and wheat are the most important species and contribute 53 and 22%, respectively, to the total crop residues available. In Sri Lanka, the major crop residue is also rice straw, with about 50% used as animal feed (Perera, 1992).

Feed deficits exist throughout South Asia as a whole, with significant regional variations. However, the extent of these deficits is not clear because of differences in the methods used to calculate the data. For example, estimates based on grain yield and grain/straw ratios tend to over-estimate the availability of crop residues when, in fact, only a proportion of the total biomass produced is utilised by animals. Additionally, calculations of the nutrient requirements of animals, usually based on standards from developed countries, tend to inflate their needs and magnify the deficits. Kelley and Rao (1995) have questioned the increasing shortfalls in feeds reported in the literature in India, and suggest that it is unlikely that the dramatic increases in large ruminant production achieved in the last two decades would have been possible without some improvement in feed availability per animal. A comparison of the feed balances for 1967–1969 and 1986–1988 by Kelley and Rao (1995) shows that, in terms of hectares per animal at the national level, there was a decrease in the area under fodder crops and common property resources, whilst the area of fallow land remained constant. On the other hand, substantial increases were observed in the availability of cereal straws and agro-industrial by-products. Clearly, there is a need for more rigorous methodologies to estimate the availability of feed resources in the sub-region.

4.3. Animal health and diseases

Diseases are also a major constraint to livestock production in South Asia (Devendra et al., 2000). Animal health issues are barriers to trade in livestock and their products, whilst specific diseases decrease production and increase morbidity and mortality. A wide range of infectious and other diseases caused by bacteria, parasites and viruses are prevalent, and the major ones are common to all countries of the sub-region. Additionally, there are reproductive, metabolic and mineral disorders in ruminants, and toxicosis in animals raised in peri-urban and urban areas as a result of environmental pollution and feed adulteration (Thomas, 1999). The major diseases include foot and mouth, haemorrhagic septicaemia, rinderpest, black quarter and anthrax in large ruminants; sheep pox, pestes des petits ruminants, blue tongue and enterotoxaemia in small ruminants; and Newcastle disease, Gumboro disease, fowl pox and coccidiosis in poultry. Mortality, morbidity and economic losses can be high. For example, in Bangladesh, foot and mouth disease outbreaks occur at least twice annually. In every outbreak, around 50% of ruminants are affected, and the annual economic loss is estimated at US $125 million (Devendra et al., 2000). Anthrax, black quarter and haemorrhagic septicaemia outbreaks occur sporadically, resulting in up to 40% mortality in cattle and an annual loss estimated at US $2.3 million. In India, the direct loss to foot and mouth disease is estimated at more than US $430 million annually. Additionally, animal products are not accepted by other countries, reducing further the export potential of the sub-sector. In Pakistan, the overall annual losses due to diseases are estimated at US $200 million.

Disease diagnosis and monitoring systems are weak in the countries of South Asia, as is the understanding of the epidemiology of the important diseases. Thus, there is relatively little information on the incidence of diseases, their geographical/seasonal distribution or dynamics. In India, for example, there is no organised system for disease reporting (Devendra et al., 2000). The existing system is passive and does not report the confirmation of a disease. A lack of reliable data is interpreted as the absence of the disease. An All-India project has now been launched by the Indian Council for Agricultural Research (ICAR) to monitor and survey animal diseases, and has already made an important contribution to the development of simulated animal disease-forecasting models.

Vaccines are produced to some degree in all countries, but they are often inadequate to meet national needs and there are problems of quality control. Biotechnology has yet to play an important role in this area. Veterinary delivery systems are also inadequate in many of the countries. On the other hand, in India, where animal health is the responsibility of the state governments, the number of clinics, veterinary hospitals and dispensaries increased in number from 2044 in 1992 to 21,718 by 1994, complemented by 20,044 first-aid centres (Devendra et al., 2000). This veterinary infrastructure also receives support from 250 diagnostic laboratories. By the turn of the century, there will be one veterinary unit to meet the needs of 5000 large ruminant units or 10 villages.

4.4. Other factors

The development of the livestock industries is also limited by poor infrastructure (Vercoe et al., 1997). This includes finance, transport, skilled labour, processing facilities, storage, marketing, and the delivery of advisory and health services. The processing of livestock products demands very high standards of hygiene, an adequate supply of high-quality water, and a trained workforce. Product storage often requires a constant supply of electricity for refrigeration, which is costly and cannot be guaranteed on a regular basis. Suitable transport for the product is uncommon and, consequently, the products often arrive at retail outlets in a poor state.

Marketing of animals in small-scale production systems is a major problem. Marketing chains are often poorly defined, complex and inefficient and are not conducive to the delivery of livestock or their products in good condition. This is particularly the case for small ruminants. Government interventions in the production and marketing chains, to provide incentives, have often been far from successful and, sometimes, counter-productive.

The ability of small-scale livestock producers to improve output may be limited by the lack of adequate advisory services. The institutional base required for successful technology transfer and uptake will need to be strengthened to improve the impact of existing and new technologies.

5. Opportunities for research

Major research and development opportunities exist to increase livestock productivity in the mixed farming systems of South Asia (Devendra et al., 2000).

5.1. Overcoming the constraints

The conventional technological approaches to enhancing animal productivity are well documented (e.g. Vercoe et al., 1997). Enhancing the supply of nutrients to livestock can be achieved by improving the availability of local foodstuffs (new forage crops, agricultural by-products, and non-conventional feed resources), improving the efficiency of utilisation of feeds (rumen manipulation, supplementation, and treatment/processing), and increasing imports. Comparative studies on the epidemiology of important diseases will produce useful leads for control strategies, and significant improvements can be made in vaccine development. Improving the genetic base of livestock through cross-breeding has been a priority area, particularly in production systems where expensive and imported feed resources have been a significant part of their nutrition.

5.2. Component technology versus farming systems research

It is clear from the low productivity of animals in South Asia that inadequate progress has been made in the application of new interventions at farm level. Technologies have either not been adopted or their uptake has not been sustainable. Research in animal production has too often highlighted component technologies within the disciplines of nutrition, health and breeding. Small-scale mixed farming systems have been treated as a single production unit, despite their diversity and complexity, and a blanket approach taken in the case of technology transfer. Research has not been multi-disciplinary and, therefore, has failed to take account of the interactions that occur at farm level between genotype, nutrition, management and diseases. From a substantial review of some 3340 papers from South Asia, Devendra et al. (2000) reported a paucity of information on research that incorporates animals interactively with cropping, and a woeful neglect of social, economic and policy issues. Much of what is defined as farming systems research is nothing more than a study of cropping patterns. Subsequent visits to the countries by Devendra et al. (2000) confirmed that research, conducted by the national agricultural research systems (NARS), lacked a farming systems perspective and that disciplinary barriers to a more holistic approach existed in all institutions. Some examples of component technology interventions will now be given.

Crossbreeding of indigenous stock with exotic animals is acknowledged widely as a valuable strategy for rapidly increasing production, through the exploitation of hybrid vigour. The best example of crossbreeding throughout South Asia is the use of temperate cattle to improve the milk yields of native breeds. Spectacular increases in production have been achieved and, generally, first-generation crosses produce significantly more milk than the indigenous pure breeds (Doornbos et al., 1990; Samdup, 1997). However, such schemes are often difficult to sustain, and there are problems in developing practical policy guidelines to ensure a consistency of approach. The priority given to crossbreeding is one of the reasons for the incomplete characterisation of indigenous breeds and the lack of emphasis on selection programmes for such breeds. The problems associated with crossbreeding have been summarised by Devendra et al. (2000). Firstly, such programmes have lacked co-ordination within and between countries, with a range of exotic breeds being used randomly for crossbreeding. Recently, in countries such as India, organisations such as the National Dairy Development Board have attempted to rationalise the improvement of large ruminants (NDDB, 1998). Secondly, programmes have been constrained by difficulties with artificial insemination at farm level and the poor availability of high quality breeding stock. Additionally, fertility problems have been encountered that are accentuated by poor nutrition. Thirdly, the level of exotic blood in the crosses is highly variable at farm level, ranging from 25 to 75%, despite a general agreement that the first-generation crosses represent the optimum state. In most countries, farmers are even demanding pure exotic breeds when their overall management skills, feeding regimes and hygiene are clearly inadequate. Fourthly, the productivity levels achieved on experimental stations and government farms are seldom achieved at small farm level, because of the poor nutrition, hygiene and management. Often, animal health problems (e.g. tick-borne diseases), that were not evident with indigenous breeds, become more important as crossbreeding evolves. At farm level, there are interactions between genotype, nutrition and disease that are seldom examined in the research agenda. Finally, perhaps the most damaging effect of the widespread development of crossbreeding is the genetic erosion of indigenous breeds and the threat of ultimate extinction. This effect has been well documented recently for a wide range of domestic livestock species in India by

Khurana (1997). An ironic situation has arisen where that country is now importing its indigenous genotypes from other countries, where valuable genes from these species have even been patented. In Pakistan, the number of pure Sahiwal cattle in Punjab province (originally thought to be 100,000) has fallen to below 6000 in 12 out of 16 districts (Devendra et al., 2000). In Bhutan, only 191 pure mithun exist compared with 65,000 mithun-cattle crosses. Unfortunately, vested interests in developed countries (often through aid initiatives) have done a disservice to developing countries by promoting and exporting breeds for genetic improvement that are not appropriate for small-scale farming systems and lack adaptation to the prevailing environmental conditions.

A vast amount of attention has been paid experimentally to the chemical and biological treatment of cereal straws (Chaudhry, 1998). Of the many treatments tried in the different countries, the urea–ammonia technique has emerged as the most effective, practical and relevant (Schiere and Ibrahim, 1989). The justification for this conclusion was the increased digestibility and higher intake resulting from the treatment (Chesson and Orskov, 1984; Ghebrehiwet et al., 1988). Recently, Devendra (1997) reviewed past research on urea–ammonia straw treatment, and concluded that far too much attention has been paid to the practice at the expense of supplementation strategies. Much of the work has been confined to the research station, with few attempts to transfer the technology through large-scale testing on farm. The failure to demonstrate cost-effective results has discouraged farmer adoption, which remains very low in South Asia. An alternative strategy is the genetic enhancement of nutritive value in cereal straws (Zerbini and Thomas, 1999).

Improved pasture species have been introduced and evaluated in experiments in the temperate and tropical zones of all of the countries of South Asia (e.g. Chadhokar, 1983; Gibson and Namgyel, 1991; Liyange, 1991; Ranawana and Perera, 1995; Shrestha and Pradhan, 1995; Bhatti and Khan, 1996). The references to pasture improvement trials in India, conducted by the various institutes of the ICAR and the state agricultural universities, are legion. Impressive results have been obtained in terms of increased yields of dry matter, improved nutritive value for livestock and enhanced soil fertility. However, the opportunities for pasture improvement in small-scale farming systems still remain to be exploited fully in the sub-region. Even in the irrigated sector, in countries such as India and Pakistan, only 3–15% of the total arable area is used for cultivated forages (Devendra et al., 2000). Hitherto, the impact on livestock production in small-scale farming systems in developing countries has not been proportional to the quantity of research literature generated since the Second World War (Thomas, 1999). Often, there has been too much emphasis on the selection of herbaceous perennial legumes, rather than self-regenerating annuals. Perennial species are often inappropriate for integration into small-scale annual cropping systems, where the fallow period has been eliminated or greatly reduced so that land is not available for exclusive pasture establishment. Riveros et al. (1993), Carter (1995) and Thomas and Sumberg (1995) have all discussed the reasons for poor adoption of improved pasture species.

6. Systems analysis

Research, policies and interventions on farm will be more effective if they are based on a sound understanding of the nature of small-scale mixed farming systems in South Asia. It is important to recognise in these systems the strong nexus that exists between crop and animal production, their complexity and diversity, and the need for differential interventions in specific systems. Additionally, some knowledge is required of the factors that influence the continued evolution of these systems.

An analysis of small-scale mixed farming systems in South Asia is being undertaken by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Livestock Research Institute (ILRI), together with the NARS in five South Asian countries (Bangladesh, India, Nepal, Pakistan and Sri Lanka) to correct the deficiencies in previous technology development. The overall purpose of the studies is to develop a crop–livestock typology for South Asia, i.e. a system of common types of production that would also allow individual production units to be considered representative examples of their group. The typology will identify regions that have similar constraints to the development of the agricultural economy, in which development initiatives can be directed to identifiable economic activities, and that are homogeneous in terms of expected outcomes in response to external changes. Such a typology for rain-fed agriculture in India, using the predominant cropping pattern as the primary integrator of numerous other variables in the production system, has already been constructed and described by Kelley et al. (1997) and ICRISAT (1998). However, the limitations of this study were that it provided an analysis of the crop sub-sector only and not the whole system, and was confined to one country. In reality, most of the systems were highly complex and diverse crop–livestock operations, and similar systems are found in all of the countries of South Asia. The methodology for creating the rain-fed agriculture typology can be adapted to create a crop–animal typology with suitable modifications. There will be a need to re-assess key integrator variables with additions and deletions. It will obviously be necessary to include a comprehensive set of factors related to the livestock sub-sector.

A novel feature of the typology reported by Kelley et al. (1997) and ICRISAT (1998) is that it integrates key agricultural, social and economic characteristics, as well as agro-ecological variables. Profitability and risk considerations, market access and transaction costs, subsistence considerations, complementarity with other activities, soil management options, and agro-ecological characteristics are all reflected in decisions on cropping made by farmers (Kelley et al., 1997). This integration is basic to the establishment of priorities for agricultural research, development and the improvement in production technologies. Previous attempts to delineate homogeneous zones, e.g. Sehgal et al. (1992) in India, have given primary importance to features that defined the agricultural production technology and determined the productivity potential such as physiography, climate and soils. Decisions related to research and policy were made for agro-ecologically homogeneous regions as a whole. However, this was a narrow approach that failed to incorporate socio-economic factors that determine the nature of constraints which limit the ability of farmers to produce more efficiently and sustainably. Agricultural activities dominate almost all rural economies, and development strategies and policy instruments must be related to specific features of agricultural activities to induce economic development of rural areas. Information on dominant agricultural activities must be an integral part of any attempt to classify districts in a country with a view to designing agricultural research agenda, making infrastructure investments or developing poverty eradication programmes for rural areas. Therefore, agricultural activities are likely to fulfil the required role of an integrator of key structural variables (e.g. aspects of the physical and biotic environments; socio-economic attributes related to livestock and markets, road density, presence of processing plants, literacy, property rights, size of landholdings, wage rates, and food availability). Agricultural activities are an articulation of the multiple objectives of the farm, within the underlying agro-ecological and socio-economic constraints of the environment (Collinson, 1996).

The objectives of the work are encapsulated in four distinct but interrelated modules. The first will involve the development of the crop–livestock systems typology for South Asia and the characterisation of these systems. The development of the typology will depend critically on the availability and comprehensive nature of good quality data, preferably time-series data from census years, at the state and district levels. However, incorporating all relevant natural and socio-economic factors that differentiate between agricultural systems is not practical. Hence, a set of key agro-ecological and socio-economic variables must be identified. Subsequent to this, data have to be examined to determine if such variables are available and accessible. A large number of censuses and macro-surveys have been conducted in the sub-region, and a vast amount of secondary data on crop and animal production collected at national, state/provincial and district levels. Although, in some areas, these sources can be inadequate and unreliable, they provide a valuable data-base that has not been exploited fully. These secondary data will be systematically collected, collated, analysed and interpreted. This will provide an overview of the role of ruminant production in these systems and in the economies of the countries, as a source of employment and products for human consumption; the importance of animals on different sized holdings in terms of numbers, the proportions of different species/classes, their different functions, their outputs (work, meat, milk, manure); the sale of animals to peri-urban and urban areas; and the pattern of ownership. The variation in these characteristics for each system in the typology will be mapped and highlighted along with the changes that have taken place in the systems over the last 20–25 years. The outputs of this module will help to demarcate homogeneous tracts according to the relative importance of the principal outputs, the species producing them, the level of development and the degree of dynamism in recent times.

In theme two, secondary data from macro-sources and micro-surveys of selected systems will be evaluated in order to examine the situation in greater depth. Gaps in the information will be filled by further micro-surveys. This will provide a comprehensive picture of the structure of selected systems, the changes that have occurred over time and will enable the factors responsible to be identified. In order to capture the great diversity that prevails in the sub-region in different situations, systematic comparative studies will be conducted in selected areas. The basic assumption is that the factors influencing structure and change can be better understood by focusing on the analysis of inter-regional and inter-district variations and on comparative studies of selected areas and systems. It is essential to view different configurations of animal production and their relationship to crop production in an integrated framework, incorporating relevant variables (Table 1).

Theme three will assess the impact of external interventions at farm level. Numerous technologies to improve animal productivity have been implemented in South Asia. These have included crossbreeding; the introduction of animal health packages; the establishment of improved forages; and the development of better processing techniques for livestock products. Efforts have been made to combine and integrate these elements in different ways and to varying degrees. In many cases, the rationale for these interventions has been supported inadequately by research, and the approach has failed to take account of the diversity and complexity of crop–livestock systems. Accordingly, farmers have either failed to adopt the technologies or their adoption has not been sustainable. Some examples of these technologies were stated earlier in this review. Existing information on interventions will be compiled from these examples. Where information is lacking, micro-surveys will

Table 1
Variables to be included in the analysis of factors influencing structure and change in selected mixed farming systems

Variables
Environmental
Rainfall (amount and distribution).
Temperature.
Edaphic conditions (physical and chemical parameters, extent of erosion, impact of manure).
Technological
Extent of mechanisation affecting the numbers of draught animals.
New crop cultivars and the types of cropping patterns affecting the availability, quantity and quality of residues and by-products used as animal feed.
New technologies introduced for the genetic improvement of livestock and the control and treatment of animal diseases.
Introduction of new processing techniques for animal feeds and products.
Organisational
Size of landholdings and effects on the numbers and composition of the livestock population and feed resources production.
Emergence of lease-markets for draught animals and the development of mechanical power for farm operations.
Growth of specialised animal production systems.
Availability of public services for animal health.
Development of storage, processing and marketing facilities for animal products.
Socio-economic
Demand for animal products (manure, meat, milk) resulting from changes in incomes, consumer preferences and urbanisation.
Feed and animal product prices.
Costs of animal production.
Economies of scale.
Social and religious implications of livestock ownership.

be conducted on the extent of adoption of the external interventions, their impact at farm level on animal production and the natural resources base, and the reasons for success or failure. As a consequence of this analysis, it should be possible to suggest more appropriate intervention strategies for the future and the institutional arrangements necessary to implement them more effectively.

Themes 1–3 will contribute to the selection of specific "best-bet" interventions to be tested on farm in selected priority systems in theme four. It is clear that a given intervention may not be relevant to all types of crop–livestock sub-systems, and that a differential application of a technology is required. The interactions and impact of new technologies with other components of the farming system will be assessed, together with effects on the natural resources base. Indicators developed for the earlier multi-donor livestock–environment study (De Haan et al., 1997) will be used for environmental assessment.

7. Conclusions

Small-scale mixed farming systems predominate in South Asia, and most of the future demand for ruminant meat and milk is expected to come from the improved productivity of animals in these systems. Despite the importance of these systems in the sub-region, there is a paucity of information on research that incorporates animals interactively with cropping. Farming systems research has tended to highlight studies on cropping patterns only, whilst livestock research has concentrated on the development of component technologies. Interventions have either failed to become adopted at farm level or their uptake has been unsustainable. Crop–livestock systems have been treated simplistically as a single production unit and new technologies applied accordingly. The need for an analysis of crop–livestock systems is advocated, which takes into account their complexity and diversity. A classification and characterisation of these systems is necessary to identify recommendation domains for differential technological and policy interventions in the future. The work will provide a link between the nature of the systems and the research and institutional management approaches required to improve them. Additionally, the study will strengthen capacity in systems analysis in the NARS.

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