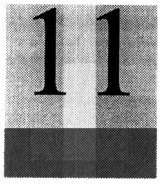

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Smallholder Dairy Production Systems in East and South-East Asia: Expanding Importance, Environmental impacts and Opportunities for Improvements

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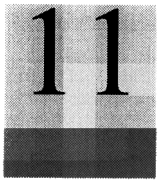

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Smallholder dairy production systems in East and South-East Asia: Expanding importance, environmental impacts and opportunities for improvements

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Abstract

Smallholder dairy production systems in East and South-East Asia are discussed with reference to type of systems, characteristics, potential importance, environmental impacts and opportunities for improvement. Key features of the industry include: rapid expansion and increasing consumption of milk; a means to generate ready income; significant benefits to child nutrition; effects on poverty reduction and stability of households; strong market orientation; and promotion of linkages between rural and urban areas. Three types of dairy systems are identified and described: smallholder systems, smallholder co-operative dairy production systems and intensive dairy production systems. The first two systems are by far the most important and are associated with increasing intensification and specialisation. Dairy production mainly involves the use of Holstein–Friesian crossbred cattle. The expansion and intensification of smallholder dairy production is fuelled by an increased demand for milk, but is associated with problems of milk handling and distribution, hygiene and environmental pollution. The major constraints to production are, *inter alia*: limited choice of species; poor breeding programmes and unavailability of animals; lack of feed resources and inefficient feeding systems; poor management of animal manure; poor hygiene and human health hazards; and lack of organised marketing and market outlets. Specific areas for research and development, and opportunities for improved dairy production in the totality of production to consumption systems are identified; suggestions for performance indicators in such systems are included. A holistic focus involving interdisciplinary research and integrated natural resource management is necessary in shared partnerships between farmers and scientists to demonstrate increased productivity and sustainable dairy production systems.

Introduction

Smallholder dairy production in East and South-East Asia is a particularly important avenue of food production from cattle, buffalo and goats. Unlike South Asia where there is a strong tradition of milk consumption, in East and South-East Asia, dairy production is expanding in importance and milk is consumed increasingly widely by the younger generation. These aspects and potential future impact are associated with a number of key features, which *inter alia* include:

- Rapid expansion, increasing consumption and strong market demand
- Recognition of the advances and impacts made in India through Operation Flood
- A means to generate ready income, build assets and socio-economic benefits
- Significant benefits to child nutrition
- Impact on poverty reduction and household stability and
- Potential for increasing the current level of production.

Among ruminant production systems, dairy production systems are by far the most dynamic. Dairying systems are influenced greatly by the reality and instant benefits of daily milk production, immediate sales to urban markets, linkages between rural and peri-urban areas, and public and private sector participation. The daily movement of one or more forms of transport to collect milk produced on the farm, delivery to milk collection centres for immediate processing, subsequent delivery to urban areas, the concurrent delivery of purchased feeds and drugs, and contact with extension personnel, clearly reflect the dynamic linkages that exist between rural and urban areas, and their development. Many of these issues are interrelated with changes in one factor invariably affecting the other; when these issues are viewed in holistic terms, the dairy sector provides major development potential.

It is not surprising therefore that all governments in the region, without exception, have given particular attention to the promotion of dairy development. China, for

example, has placed major emphasis on the dairy industry while it also stabilises the production of pork and poultry (Zhang 2001). The situation in China is interesting and is reflected in the following facts:

- Decentralisation of milk production from government-controlled state farms to smallholder units since the early 1980s
- Thrice a day milking to maximise milk production and sales
- Priority to dairy development because of its impact on child nutrition and school milk programmes
- Promotion of dairy development through microcredit schemes
- Evidence of a 100% return rate to credit schemes on account of daily income generation through the sale of milk
- Together, these aspects have fuelled rapid expansion of the industry with some replacement of pig production by dairy activities.

In tandem with this development, most governments in the region have therefore made direct interventions in various forms to include policy elements and also subsidies. Additionally, the industry as a whole has strong production and post-production components, and also involves widespread participation of the private sector. In view of the rapid expansion and variable levels of development in East and South-East Asia, the opportunities for improved dairying and development of more sustainable production systems are considerable. Major challenges exist therefore in examining and improving the prevailing dairy production systems, current levels of production and post-production systems. The task is compelling at a time when available supplies of milk are unable to meet either the current or the projected future demand for milk, bringing into question the efficiency of individual animal production systems in Asia (Devendra 2001).

This paper provides an overview of the types and characteristics of smallholder dairy production systems in East and South-East Asia, and current supplies and projected demand for milk. It discusses policy and institutional issues, marketing, environmental impacts, and constraints and opportunities, and alludes to major research and development issues that will need to be addressed to sustain and expand smallholder dairying in the future.

Current production and projected consumption

It is important to keep in perspective the current production levels and projected future consumption patterns. Table 1 illustrates the levels of milk production and consumption during 1992–94. These data suggest that per capita milk production was inadequate to meet per capita milk consumption in China and South-East Asia, whereas in other East Asian countries, milk production was surplus to per capita consumption. In South-East Asia, per capita milk consumption was substantially higher than production in 1993. The annual growth rate of production was negative in China and relatively small (1–2%) in South-East Asia.

Table 1. *Milk production and consumption, 1992–94.*

Region	Productivity (kg)	Annual growth rate of production* (%)	Per capita production** (kg)	Per capita consumption** (kg)
China	1530	–1.6	6	7
Other East Asia*	1983	5.1	30	16
South-East Asia	628	1.2	3	11
India	973	2.4	66	58
Other South Asia	538	5.1	62	58

* For 1982–94.
** For 1993.
+ Includes Hong Kong, Macau, Mongolia, North and South Korea.
Source: adapted from Delgado et al. (1999).

Table 2 presents data relating to projected milk production and consumption up to the year 2020; data were adapted from Delgado et al. (1999). Both annual growth rates of production and consumption are projected to increase in the future. More importantly, a comparison of per capita production and per capita consumption levels, as well as total production and consumption in China, other East Asian countries and South-East Asia, indicated that only in the latter subregion would supplies be unable to meet consumption requirements. The percentage increase in per capita consumption of milk between 1993 and 2020 indicates increases of 71.4, 25.0 and 45.5% in China, other East Asian countries and South-East Asia, respectively. Data in Table 2 also indicate the level of adequacy in the three subregions. Although by 2020, self-sufficiency will be achieved with surpluses in China and other East Asian countries, the pathway to achieve this will call for significant expansion and improved efficiency of production, and in particular, improvements to all the factors affecting production. Conversely, South-East Asia will not be self-sufficient in milk production and will continue to be reliant on imports of milk at high cost. For comparative reasons, in both Tables 1 and 2, data are included to show the trends in India and other South Asian countries.

Table 2. *Projected milk production and consumption, 1993–2020.*

Region	Annual growth of total production (%)	Annual growth of total consumption (%)	Per capita production in 2020 (kg)	Per capita consumption in 2020 (kg)	Level of sufficiency	Increase in per capita consumption by 2020 over the level in 1993 (%)
China	3.2	2.8	13	12	Adequate	71.4
Other East Asia+	3.9	1.7	29	20	Adequate	25.0
South-East Asia	2.9	2.7	5	16	Inadequate	45.5
India	1.6	4.3	135	125	Adequate	115.5
Other South Asia	3.1	3.4	92	82	Adequate	41.4

+ Includes Hong Kong, Macau, Mongolia, North and South Korea.
Source: adapted from Delgado et al. (1999).

The data in Tables 1 and 2 indicate that in both China and South-East Asia, major opportunities exist to address improved dairy production, not only in terms of increasing individual animal performance in efficient production systems, but also by improving other factors such as post-production systems and marketing, which are associated with organised dairy production.

Implications of increased demand

The projected need for more foods of animal origin in Asia has a number of demand-driven consequences, which also need to be addressed. These include *inter alia*:

- Stress on the management of natural resources
- Emphasis on increased productivity per animal
- Improved efficiency in feed resource use
- Intensification of animal production systems

- Increased concentration of animals in smallholder areas
- Increased disease risks, pollution and human health issues and
- Urbanisation associated with increased consumption of meat and milk

Types and characteristics of smallholder dairy production systems

Three types of smallholder dairy production systems exist:

Smallholder systems

Ownership of between 2 and 15 animals characterises this system, in which milk production is a major component of farm income. Either buffalo or cattle are kept in essentially mixed systems where annual cropping is common; in addition, pigs and chicken are also reared. Good market opportunities are important determinants and this system tends to be found mainly in peri-urban areas. Milk production contributes about 35–65% of total farm income in several countries in Asia. Occasionally, dairy goats are also used in these systems. The dairy animals are either tethered or stall-fed. Some of the milk produced is used for home consumption, but most is sold directly by farmers or through middlemen who transport the milk to urban areas or processing units. Most of the systems are of a subsistence nature. The resource-poor situations of the smallholders have prevented intensification and specialisation, mainly because of a lack of access to services and resources. On the other hand, where land is not limiting, and access to credit, resources and market opportunities exist, smallholders have tended to expand their herds and have increased milk production. Some farmers process condensed milk: 2.2 litres of fresh milk and 450 g of white sugar are used to produce 1 kg of condensed milk which is then sold to coffee shops and factories. In Vietnam, income from the sale of condensed milk is higher than that from selling fresh milk (Cuong et al. 1992). An important feature in this category is informal milk marketing.

One important characteristic of these smallholder dairy production systems is their rapid expansion in smallholder areas, driven essentially by the urban demand and the opportunities to generate income. Consequently, there has been increased smallholder participation in this enterprise and, with it, expansion in the geographical areas that constitute smallholder limits. Good examples of this are Bangkok and Khon Kaen in Thailand, Ho Chi Min City in South Vietnam and Beijing in China. With Ho Chi Min City, for example, smallholder dairying operations involved a radius of about 60 km around the city in the mid-1980s, but have now expanded to over twice this radius.

Smallholder co-operative dairy production systems

These systems are more advanced and mature, in comparison with the first category of systems. They are formed from a natural aggregation and concentration of smallholder dairy units. Their formation is due to government and/or private sector intervention driven by an apparent necessity and varies from country to country. In India, for example, formation of these co-operatives occurred because of both types of intervention; in contrast, in the countries of South-East Asia, co-operatives are the result of direct government intervention. Due to differences in the types of intervention, the size of co-operatives varies and larger co-operatives are emerging, involving anything from 40–250 smallholders. This kind of commercial smallholder dairying is growing rapidly around major cities. The co-operatives are focal points, which provide services to farmers as well as promoting the organised collection, handling and sale of milk to consumers. Co-operatives enable the smallholders to improve their competitive edge in open-market economies. Good examples of this system are found in several areas, especially in proximity to major cities, as found in Thailand, the

Philippines, Vietnam and China. In the Philippines, for example, specific government intervention includes the promotion of dairy co-operatives for groups of farmers producing milk from swamp × Murrah cross-breds and also from Holstein–Friesian cattle crossbreds.

Two examples of this category are instructive. The first is in the Nang Pho Dairy Co-operative, Ratchaburi Province, about 100 km south of Bangkok in Thailand. A survey of 43 farms indicated that 95% of them were <0.32 ha in area (Skunmun et al. 1999). A more recent survey of 10 farms in the same area gave a range of 0.02–0.48 ha. Most farms had between 0.32–1.12 ha of additional land, mainly rented or owned to grow fodder. The majority of cattle sheds were attached to the house or were between two and five metres from the house. The net cash return (as a percentage of total income) was 68.9% and the average cost of milk production was US$ 0.22/kg (Skunmun and Chantalakhana 2000). The authors suggested that attention to the following areas could further reduce the cost of production: feeds, reduction of the number of herd replacements and maintenance of production records. It is interesting to note that from dairy operations alone, only three farms made profits, emphasising the importance of crop–animal systems and also the scale of operations.

Another example, on a much larger scale, is the Landhi Cattle Colony in Karachi, Pakistan, which has about 220 thousand animals in a 5-km radius. About 95% of these animals are buffalo and 5% are cattle of which half are crossbreds. It began originally as a mechanism to concentrate animals outside the city limits, but has grown into a large and complex enterprise within the city. Pregnant animals are purchased from rural areas and exclusively stall-fed on cereal straws, green fodders and concentrates. Female calves produced are sold, except for a small number that are kept as replacements for breeding. Male calves are fattened for four months and slaughtered. At the end of their lactation, the original females are also slaughtered. Indiscriminate growth of the colony, without regulatory and policy interventions, has resulted in a serious situation, which is made more complex by very poor hygiene, health hazards such as contaminated ground water, ever increasing quantities of unused manure and other impacts on the environment.

Intensive dairy production systems

The third category of smallholder dairying is intensive production systems. The expansion of smallholder dairy production, increasing experience and open-market opportunities have led to the development of more intensive and specialised production systems. This trend is reflected in Table 3, which shows that small and marginal farms, and medium and large farms contributed 42 and 35% of the volume of total milk produced.

Table 3. *Distribution of dairy animals and milk production among landless, small/marginal and medium/large-scale producers in India.*

Type of farmers	% of farmers	% of dairy animals	% of milk production
Landless	26	22	23
Small and marginal	49	42	42
Medium and large	25	36	35

Source: Jong (1996).

These relatively large, intensive and increasingly specialised systems are characterised by the following features:

- Relatively large numbers of animals, about 60–250/per farm, involving both buffalo and cattle
- Application of improved stall-feeding systems using purchased chopped straws, green fodder and concentrates at high cost
- Use of capital intensive infrastructure e.g. dairy equipment and other inputs and
- Existence of well-organised marketing systems and access to markets.

Within smallholder dairy systems, however, intensive dairy production units are least in number and are usually in the hands of more knowledgeable dairy farmers, who also have access to credit facilities and services.

Considered together, the three types of smallholder dairy production systems have the following features:

- They occur commonly in peri-urban areas and are distinctly market-oriented.
- They are a component of integrated crop–animal production systems.
- Purebred Holstein–Friesian cattle, their various crossbreds including Holstein–Sahiwal crossbreds are used widely. In the Philippines and the south-western parts of China, in the Guangxi and Yunnan Provinces, swamp × river buffalo crossbreds are also used for milk production.
- The level of exotic blood is highly variable and ranges from about 25 to 75% on farm. Crossbreeding programmes have generally not been successful, including the production and use of stable crossbreds.
- Short-term productivity gains from use of crossbreds are considered to be more important, as they bring immediate benefits, than the rational use of indigenous breeds and maximisation of their production through selection.
- The choice of buffalo and cattle for milk production is dependent on location, as well as availability of animals.
- Dairy goats are used marginally for milk production, especially in China but also in Vietnam and Indonesia, where they supply precious animal proteins for household nutrition.
- There seems to be little or no data comparing the efficiencies of milk production between indigenous buffalo and cattle, cattle crossbreds and goats in smallholder systems.
- In socio-economic terms, dairying provides an attractive means to generate daily income. This has important implications on human nutrition, participation of women, household stability, repayment of loans and self-reliance.
- Expanded and demand-driven dairy production has led to intensification and specialisation of smallholder production systems, with emerging problems relating to milk handling, hygiene and environmental pollution, and to human health hazards.
- Intensification has limited the ability of smallholders to compete with larger enterprises because of smallholders inadequate access to subsidies, which benefit larger farmers. Removal of these subsidies provides better opportunities for the smallholders and
- Women and children are heavily involved in the milking and management of dairy animals.

Constraints to production

There are several constraints to production, which include *inter alia*:

Choice of species and breeds within species, and availability of animals for dairying. The latter accentuates dependence on the importation of animals and germplasm

2. Poor breeding programmes and lack of availability of stable crossbreds
3. Lack of feed resources and inefficient feeding systems with associated high costs of milk production
4. Limited management of animal manure and urine
5. Poor hygiene and human health hazards
6. Lack of organised marketing and market outlets.

It is not intended to discuss these constraints to production in detail, given the focus on these issues in the country case studies, but it is relevant to highlight some of the more important issues because it is necessary to overcome emerging problems.

Choice and availability of animals

Buffalo and cattle are used for dairying with complementary advantages, but a more serious problem is the availability of animals. Often good quality Holstein–Friesian crossbreds are not available or their cost prohibits use by small farmers, unless the animals are made available by government schemes. Several countries in the region have therefore embarked on massive importations of germplasm in the form of live animals, and frozen semen and ova from various industrialised countries. Nevertheless, sustainable breeding programmes are necessary to ensure the continuing availability of dairy animals. Many of the larger farms attempt to produce their own crossbreds mainly through artificial insemination (AI), but not without problems associated with the application and associated costs.

Feed resources and improved feeding systems

Feeding and nutrition have repeatedly been highlighted as the major constraints in animal production systems globally (ILRI 1995) and subregionally in South-East Asia (Devendra et al. 1997). Improved animal nutrition in dairy production is therefore a major consideration.

Of the non-genetic factors affecting production, this is especially important since cost of feeding accounts for about 40–60% of the total cost of milk production in intensive systems. In smallholder systems, inadequate land and size of operation are further constraints on production. In the cooler temperate Beijing area of China, dairy production has expanded significantly through the integration of triticale into the cropping system, as a replacement for barley during the winter–spring period. This has involved a shift from rice cropping alone to rice–triticale double cropping, resulting in higher grain and forage yields, increased silage production, improved composition of milk from dairy cows, increased economic benefits from grain–forage cropping systems compared with grain–grain cropping, and dairy production (Wang et al. 1993).

It is important, therefore, that improved feeding systems and improved efficiency of feed use are viewed clearly in a farming systems perspective. In this context, the following prerequisites are considered important:

- Knowledge of availability of all feeds (forages, crop residues, agro-industrial by-products and non-conventional feed resources) throughout the year
- Synchronisation of feed availability to requirement by animal species
- Assessment of the extent of feed surpluses and deficits
- Development of strategies to cope with the shortfalls
- Increased feed production (e.g. production of multipurpose tree legumes and development of food–feed systems)
- Justification for purchased concentrates
- Priorities for use of crop residues
- Development of feed conservation measures and
- Strategic supplementation for milk production, especially during critical dry

seasons

In many situations, long dry periods of between four and seven months, such as in the eastern islands of Indonesia, north-east Thailand, central Vietnam, many parts of China and countries in South Asia, result in inadequate availability of feeds. Furthermore, feeds that are available at this time are of poor quality, which further exacerbates animal productivity. In such environments, it is therefore essential that all avenues for feed production be considered with the main objective being to ensure the maximum possible availability of animal feeds. In this context, the development of a food–feed system is an important strategy. The system is one that maintains, if not increases the yield of the food crop, sustains soil fertility and provides dietary nutrients for the animals. The subject, together with various case studies, has recently been reviewed (Devendra et al. 2001).

These prerequisites need to be considered in holistic terms to promote efficiency in feed resource use and, associated with this, increased productivity of the animals. In the absence of such a holistic focus, research and development efforts concerning feed resource use will continue to be of a 'piecemeal' approach, mainly component technology interventions with variable success rates.

Improved animal health care

Improved animal health care is also essential as it imposes a serious source of loss. Diseases often rank, with the availability of feed resources and nutrition, as the major constraints to production. A variety of diseases (e.g. mastitis and brucellosis) affect the calf and milking cow. Losses due to disease are variable across countries and are dictated largely by the level of management, knowledge base, access to drugs and services, and the efficiency of extension services. Losses are naturally greater in the high number of newer farms and much less in the more established farms where efficient preventive health care and treatment can overcome the disease problems.

In many parts of South-East Asia, proliferation of new dairy farms is challenged by disease problems, often through poor hygiene as a source of loss. Government and private sector interventions have been concerned largely with reducing the losses through provision of appropriate medication. In peri-urban areas, an emerging problem that will need increasing attention is the hazard to human health associated with intensive and stall-fed dairy production.

Management of animal manure

Animal manure produced on farm, represents a major health hazard. The problem increases with increasing herd size and intensification, and is associated with a number of issues including: quantity and quality of manure and urine produced; inadequate removal, frequency of removal and storage in proximity to where the excreta is produced; labour availability; methods used for manual disposal; value and use of dung; and linkages to rural areas. In most situations, the systems for manure management and use are very haphazard and present serious problems to both animals and humans. The human health hazards in intensive smallholder systems are much more serious than initially realised, because of inadequate supervisory and sanitary measures, without which the situation can worsen. This was highlighted in an investigation on the effects of dairy wastes on water and soil resources in smallholder dairy systems in Thailand (Chantalakhana et al. 1998). Results showed that:

- Waste water from older established dairy barns and crowded farms constituted a great risk to the environment because of the high COD (chemical oxygen demand), BOD (biological oxygen demand) and presence of coliform organisms

- Both wastewater and leaching, from piled up manure and manure drying on bare surfaces were implicated in ground water contamination
- Waste water from dairy farms, well water and public waterways in the locality all provided evidence of a cumulative problem associated with a lack of effective waste management practices, therefore constituting critical sites for monitoring and
- Monitoring of wastewater could be based on relatively simple tests that correlate broadly with more sophisticated chemical and biological tests.

Organised marketing and market outlets

The high demand for milk and milk products necessitates an organised link with production. Availabilities of a market drive, organised marketing and access to market outlets are therefore important prerequisites for the distribution and sale of milk produced. In the absence of these, prospects for promotion of efficient milk production will always be vulnerable and a risk.

Environmental impacts

One important consequence of expanding dairy production, intensification and specialisation of traditional systems is the need for efficient manure and urine waste disposal systems. Large concentrations of animals, poor infrastructure, the movement of animals, poor husbandry and unhygienic milk handling systems are sources of major disease outbreaks and threats to human health. In general, efficient waste disposal systems are not in place and are often non-existent; in consequence, dairy wastes present a major health hazard for humans. The situation becomes more serious in peri-urban areas and is compounded by poor infrastructure, and lack of regulations, monitoring and enforcement. Zoonotic diseases such as tuberculosis and brucellosis can be passed to humans. Depending on the proximity of the dairy wastes to cities, these and other diseases may spread to human populations. Additionally, concentrations of animals and their wastes produce various gases (carbon dioxide, methane and nitrous oxide), which have detrimental affects on the atmosphere and global warming.

Nevertheless, the presence of efficient collection and disposal systems for manure and urine can promote their beneficial use. When returned to the field to fertilise crops and fodder, dairy wastes can contribute to the increased availability of feeds for dairy animals. Such nutrient transactions also promote linkages between rural and peri-urban areas.

Opportunities for improvement

Feed resources and improved feeding systems

Improved feeding systems that ensure optimum performance, and efficient and low cost milk production need to consider the following issues:

- Feed availability and feeding systems
- Seasonality of production
- Basal roughage resources
- Strategic and effective use of supplements
- Access to low cost and potentially important feeds and
- Extent of use of feed resources from the farm.

Associated with the above, it is pertinent to note four important points that are relevant to feeds and feeding:

- Ruminant production systems are unlikely to change in the foreseeable future. Proposed new systems and returns from them would therefore have to be demonstrably superior and supported by massive inputs of capital and other resources (Mahadevan and Devendra 1986; Devendra 1989). However, there will be increasing and predictable intensification and a shift within systems. This situation is increasingly likely with decreasing availability of arable land. The principal aim should therefore be to address improved feeding and nutrition, in which the objective is maximum use of the available feed resources, notably crop residues and low quality roughage, and various leguminous forages as supplements.
- During the recent Asian economic crisis, the smallholder dairy farms that collapsed were those which depended on the use of imported feeds, notably maize and supplements
- Good profits from dairy production systems accrue from systems that use the maximum possible amount of indigenous materials, especially feeds. An approach that promotes and maximises such use and self-reliance is therefore essential and
- The quality and quantity of manure and urine produced depend on the type and quantity of feeds used. Improvement in intake, digestibility and output of manure can be ensured by feeding good quality green forages and crop residues, as well as by strategic use of protein supplements.

Year-round feeding systems

A parallel strategy concerning opportunities to increase feed availability is the objective of developing sustainable year-round feeding systems. In this quest, maximising feed production is essential. The following approaches are feasible:

1. Intercropping with cereal crops
2. Relay cropping
3. Food–feed cropping systems
4. Intensive use of available crop residues
5. Forage production on rice bunds
6. Alley cropping and
7. Three-strata forage systems in dry land areas.

Priorities for the use of crop residues

Given the range of crop residues available, priorities for their use are essential in prevailing animal production systems. These priorities will depend on the quantities available, relative nutritive values, the potential value to individual ruminants species, the state of knowledge regarding their use to enhance animal production, and the potential for technology transfer and application. Table 4 summarises the three categories of crop residues, their nutrient potential and the animal species that make the best use of them. These aspects have been reviewed elsewhere (Devendra 1997 and 2000).

Table 4. *Factors affecting crop residue use by animals in Asia.*

Type of residue	Nutrient potential	Species (product/service)*
Good quality (e.g. oilseed cakes and meals, cassava leaves)	High-protein, high-energy supplement, minerals	Pigs, chicken, ducks, ruminants (meat, milk)
Medium quality (e.g. coconut cake, palm kernel, sweet potato vines)	Medium-protein	Pigs, chicken, ruminants (meat, milk)
Low quality (e.g. cereal straws, palm press fibre, stovers)	Low-protein, very fibrous, bulky	Ruminants (meat, draft), camels, donkeys, horses (draft)

* Ruminants refer to buffalo, cattle, goats and sheep.
Source: Devendra (1987).

Management of animal manure and nutrient recycling

Crop production in developing countries depends largely on the use of organic manure from animals. Inorganic fertilisers are often too expensive or unavailable to farmers who wish to use them; this emphasises clearly the importance of animals, the value of crop–animal integration and interactions, and the contribution of animal manure to sustainable agriculture. Organic materials have been used, widely and beneficially, to improve soil fertility and crop yields. In north-east Thailand, for example, where 80% of the soils are of the sandy type, animal dung continues to be very valuable for crop production (Supapoj et al. 1998). The use of animal dung in crop cultivation serves directly to supply the soil with nitrogen, phosphorous and potassium. The dung improves the physical, chemical and biological properties of soil, including improvements in soil structure and nutrient availability, and infiltration and water retention capacity, and stimulation of nitrogen fixing soil bacteria (Turner 1995). Additionally, humus in the dung improves soil pH value and therefore, phosphorous release. For reasons of cost, farmers often use a combination of inorganic fertilisers and organic materials to improve soil organic matter and soil fertility.

A considerable quantity of under-utilised and inefficiently used animal manure and urine is available in smallholder dairy units; improvement of its use to increase agricultural productivity represents a major challenge.

Opportunities for research and development

The improvement of smallholder and market-oriented smallholder dairy production in smallholder and rain-fed mixed farming systems offers considerable research and development opportunities. Many of the improvements in dairy production through crossbreeding and through various interventions in animal nutrition and health have been supply-driven, without farmer participation and conducted on experimental stations. Component technologies that have been validated on farm have seldom been adopted. A lack of farming systems perspective has meant that important interactions between animal nutrition, genotype and disease, and between animal and crop production, have not been considered together. Moreover, socio-economic and policy factors that influence the dynamics of the systems have not been addressed.

Specific areas

Some specific areas, which merit research and development attention, include *inter alia*:

- Recognition that dairy activities involve the totality of production-to-consumption systems
- Better understanding of the socio-economic factors influencing the dynamics of the systems
- The effects of specific improvements and components of the systems with maximum potential for intervention
- Synchronisation of feed availability and quality with the physiological and productive needs of different species (buffalo, cattle) and genotypes (unimproved, improved) of dairy animals throughout the year
- Genotype × nutrition × disease interactions and the effects of animal health interventions
- The effects of improved nutrient flows and recycling on crop yield and crop

residue quality in mixed farming systems and
- Development of strategies for more efficient feeding of animals and nutrient recycling through the introduction of legumes into cropping patterns.

Addressing these and other issues calls for a more holistic focus involving interdisciplinary approaches, which together can affect potential improvements in a cost-effective manner.

Expanding dairy production into rain-fed areas and promotion of rural development

Dairy production, more than any other animal production system, has demonstrated spectacular growth in the linkages between rural and urban areas. The daily production, processing and consumption of milk have promoted these linkages in many countries through a network of interrelated activities. Transport and transport costs act as a constant link between rural and urban areas and integrate both these areas. The daily shipment of milk, purchased feeds and supplements, semen for AI and drugs are examples that are concerned with this process. These movements and activities increase with decreasing proximity to markets in urban areas. Rural development is encouraged further by the presence of co-operatives that provide necessary services and ensure returns to farmers.

An additional potential opportunity for further expansion concerns the use of rain-fed areas. Currently, smallholder dairy production is mainly found in the irrigated areas where land is already overused; however, potential opportunities exist for expansion of smallholder operations, especially in rain-fed lowland areas where soil moisture and crop production are relatively high. Justification for this approach, driven by the need for more food of animal origin, is associated with the following considerations in Asia:

- Available rain-fed area account for about 82% of the land area in Asia. They are found mainly in the arid/semi-arid zones but also in the subhumid zones (TAC 1992 and 1994)
- The rain-fed areas, in the lowlands and uplands, contain 51–55% of the total population of cattle and small ruminants in Asia
- Within the 86% of the total human population of Asia living in these areas, poverty and the 'poorest of the poor' are found
- Natural resource degradation is intense and
- Major challenges exist for integrated natural resource management, poverty alleviation and improved food security.

Importantly, such expansion and the associated need for more productive animals, feed production and nutrient transfer, and their collective use in smallholder dairy systems provide major opportunities to link rural and smallholder areas, which in particular will benefit resource-poor farmers. Integrated management of natural resources will be prominent and could address FAO's concept of area-wide integration, in which markets can be linked to nutrient surplus and nutrient deficit areas. However, appropriate policies and infrastructure may be needed to ensure the efficiency of this process. The promotion of linkages between rural and smallholder areas in the use of production inputs, intensification, nutrient flows and marketing of produce needs to be pursued to ensure that the activities are compatible with reduced pollution, and minimal disease risks and human health issues.

An example of how a feed in rural areas can be processed and fed to animals, and the manure produced can be processed for crop cultivation, thus linking rural and smallholder areas, concerns a plant in Jakenan, Solo in Indonesia. Rice straw is bought from farmers at 30 thousand rupiahs (Rp) per truck (US$ 1 = Rp 9511, March 2001), subjected to microbial treatment and then fed to animals at the rate

of about 3.5 kg of straw plus 3 kg of groundnut straw/head per day in stall-feeding systems. The production system is in stages, from calves to adults. The animals used are Holstein–Friesian crossbreds, which show body weight gains of 0.7–0.8 kg (live weight) per day, and dairy cattle. The former produce about 15–25 kg of dung/head per day; about a thousand kg of processed manure (PM) is produced each month. The dung produced is removed from the barns every fortnight. The wet dung is dried at 60°C, stored and bagged. This process destroys all the residual toxins, weed seeds, and micro-organisms and renders a high quality product. This is sold at 300 Rp/bag. About 250 t of PM is sold every month. The chemical composition of PM is 80% organic matter; 1.5% total N; 1.6% P2O5; 1.8% K2O; >2.8% CaO; and >0.5% Mg. The product has a pH value of 5.5–7.5.

The PM has been applied not only to rice but also to vegetables, sugarcane tobacco and potatoes. The advantages indicated include:

- Reduced cost of crop production by about 10%
- Increased rice yields by about 51% (equivalent to 2.8 t/ha). On farmers fields, the increased yields have been about 2.2 t/ha
- Similar increased yields recorded for tobacco and vegetables.

Furthermore, attempts have been made to mix the PM with poultry manure in a 3:1 ratio and to use PM in integrated systems involving dairy–fish operations. In these integrated systems, the returns as a percentage of total income are 40% from PM, 30% from dairying, 20% from sale of calves and 10% from sale of fish. This scheme is impressive and has been expanded and linked to involve several parts of Central, East and West Java, Sulawesi and Riau, in which farmers have benefited significantly in terms of increased income from the use of PM.

Sustainability

In general, smallholder systems are constrained by numerous problems including access to services, credit and resources, so much so that strategies to cope with these problems, such as diversification of resource use, represent the major objectives in subsistence systems. Over time, however, specialisation, intensification and increased income enable expansion of smallholder operations, especially among the more innovative and progressive farmers. Whether or not the systems are sustainable will depend largely on a holistic view of the enterprise, the efficiency of natural resource management, strategic use of production resources and appropriate technology that addresses the totality of production- to-consumption systems, which is highly relevant to market-oriented smallholder dairy production. It is essential that such strategies also consider long-term environmental consequences. Defined in this way, sustainable smallholder dairy production systems are those that can demonstrate:

- Efficiency in the management of natural resources and beneficial effects through crop–animal interactions (e.g. nutrient recycling)
- No evidence of resource degradation (e.g. maintenance of soil fertility)
- Promotion of maximum use of indigenous materials and a high degree of self-reliance
- Maximisation of the use of available labour and creation of employment opportunities and
- Improved livelihoods for the rural poor.

Performance indicators

The multidisciplinary approaches, coupled with integrated natural resource management need to be identified to ensure sustainable agriculture and environmental protection. This is a complex and by no means easy task, but research and development programmes need to be sensitive to these aspects in

their intent and scope, to be coupled to methodologies for efficient use of resources, to comprise appropriate technology interventions and to increase dairy production. Finally, it is important to stress in the search for the realisation of these objectives, that the research and development activities are a shared partnership between farmers and scientists in which the farmers are the target beneficiaries; the ultimate benefits need to be translated into improved livelihoods for these resource-poor farmers.

Performance indicators, hand in hand with economic analysis, largely reflect the success of the programme. Table 5 presents suggestions of some performance indicators appropriate to developing country situations, with no claims to being exhaustive. Possible performance indicators are summarised in three categories. The efficiency and management of integrated natural resources will largely determine animal performance and productivity, profitability and impact on household stability, improved livelihoods and rural development. Thus, for example, excessive use of purchased feeds and concentrates will result in high feed cost as percentage of the total production cost, implying in practice that maximum use needs to be made of all available feed ingredients as well as home mixing of these to produce desirable low cost, but effective concentrates. Likewise, improved nutrient balance and soil fertility will stimulate crop yields with increased production of feeds for animals.

Table 5. *Some performance indicators are appropriate to developing country situations.*

Type	Indicator
1. Natural resources	Increased soil fertility Reduced soil erosion Feed cost as percentage of total costs Production per unit of water Nutrient balance Positive crop–animal interactions Level of pollution Sustainability
2. Profitability	Returns as a percentage of total cost of production Return on assets Change in net worth Cash surplus
3. Households	Number of children going to school Malnutrition/human health Extent of off-farm work Stability of co-operation/revolving funds

Conclusions

Smallholder dairy production systems are expanding avenues of food production from animals in developing countries. The potential to sustain this expansion is enormous, but necessitates addressing several major constraints and issues that affect the totality of production to consumption systems, as well as the environment. The considerable research and development opportunities that exist provide major challenges for demonstration of: increased productivity from dairy cattle; efficient management of natural resources; improved livelihoods for poor farmers; and the development of sustainable production systems that are consistent with environmental integrity.

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