Smallholder Dairy Production Systems in Developing Countries : Characteristics, Potential and Opportunities for Improvement** - Review -

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ABSTRACT : Smallholder dairy production systems in developing countries are discussed with reference to type of systems, their characteristics, potential, and opportunities for improvement. Three types of dairy systems are identified and described: smallholder systems, smallholder cooperative dairy production systems, and intensive dairy production systems. The first two systems are by far the most important, and are associated with increasing intensification. Buffaloes are especially important in South Asia, but elsewhere dairy production mainly involves Holstein-Friesian cross-bred cattle. Dairy goats are important in some countries, but are generally neglected in development programmes. The expansion and intensification of smallholder dairy production is fueled by increased demand for milk with associated problems of milk handling and distribution, hygiene and environmental pollution. The major constraints to production are *inter alia*, choice of species, breeds and availability of animals; feed resources and improved feeding systems; improved breeding, reproduction, and animal health care; management of animal manure, and organised marketing, and market outlets. These constraints provide major opportunities and challenges for research and development to increase dairy production, efficient management of natural resources, and improved livelihoods of poor farmers. Specific areas for research are identified, as also the need of a holistic focus involving interdisciplinary research and integrated natural resource management, in a shared partnership between farmers and scientists that can demonstrate increased productivity and sustainable production systems. Suggestions for performance indicators in smallholder dairy production systems are indicated. ***(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 1 : 104-113)***

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INTRODUCTION

Among the avenues of food production of animal origin in the developing countries, smallholder dairy production systems are potentially very important. They are characterised by their rapid expansion, strong market orientation in rural areas, and the many opportunities for increasing the current level of production. The importance is fanned by widespread government support by this sector in many countries due to excessive imports of milk and milk products, and more importantly, because of the recognition of the influence of dairying on income generation, tangible economic benefits, household nutrition, and poverty reduction. Dairy production is also one sector that has been affected by various government policy interventions such as subsidies. It is also pertinent to emphasise that among ruminant production systems, dairy production systems are the most dynamic and are influenced to a very large extent by the reality and instant benefits of daily production of milk, immediate sales to urban markets, public and private sector participation. The daily movement of one or more forms of transport to collect milk produced on the farm and then deliver it for immediate processing to milk collection centres, as well as the concurrent delivery of purchased feeds and drugs, contact with extension personnel, clearly reflect the linkages that exist between rural and urban areas, and their development. Many of these issues are interrelated and changes to one invariably affects the other. Together, and when viewed in holistic terms, the dairy sector as a whole provides a major development potential.

These issues provide major challenges and opportunities for examining and improving prevailing dairy production systems and current levels of production. The task is compelling at a time when available supplies are unable to meet both the current as well as projected future demand for milk. The demand growth for meat and milk will be greatest in Asia, and is reflected in table 1. With specific reference to milk, the calculated deficits, allowing for the growth in production, is between 73.9 to 88.3% in China, India and South East Asia.

More importantly, the projected need for more foods of animal origin in Asia have a number of demand-driven consequences, which also need to be

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Table 1. Current production and projected consumption trends (1993-2020)

Region	*Per capita* production in 1993 (kg)		*Per capita* consumption in 2020 (kg)		Annual growth of production (1993-2020, %)		Calculated deficit allowing for the growth of production (%)
	Meat	Milk	Meat	Milk	Meat	Milk	Milk
China	33	6	60	12	2.9	3.2	73.9
Other East Asia	24	30	67	20	2.4	3.9	*
India	5	66	6	125	2.8	1.6	88.3
Other South Asia	8	62	10	82	2.6	3.1	23.4
South East Asia	16	3	24	16	3.1	2.9	76.3
World	34	93	39	85	1.8	1.6	**

* Saturation.
** Supply is in access of consumption.

(Delgado et al., 1999)

addressed. These include *inter alia*:

- Stress on use natural resources
- Emphasis on increased productivity *per animal*
- Improved efficiency in feed resource use
- Intensification of animal production systems
- Increased concentration of animal in smallholder areas
- Increased disease risks, pollution and human health issues, and
- Urbanization associated with increased consumption of meat and milk.

This paper describes the types and characteristics and potential of smallholder dairy production systems, identifies specific areas that merit research and development, and alludes to the considerable opportunities for their improvement in the developing countries. Discussion also includes issues in the development of sustainable production systems and performance indicators for such systems.

TYPES AND CHARACTERISTICS OF SMALLHOLDER DAIRY PRODUCTION SYSTEMS

There exist three types of smallholder dairy production systems:

1. Smallholder systems

The ownership of between 2-15 animals, in which milk production is a major component of farm income, characterises this system. Good market opportunities are important, and accordingly, 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. Either buffaloes or cattle are kept in essentially mixed systems where annual cropping is common and in addition, pigs and chicken are also reared. 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 of it is sold directly by farmers or to middlemen who transport the milk to urban areas or processing units. Most of the systems are of a subsistence nature and the resource-poor situations have not enabled intensification and specialisation, mainly because of access to services and resources. On the other hand, where land is not limiting, there is access to both credit and resources, and market opportunities, smallholders have tended to expand their herd and to increase milk production. Some farmers process condensed milk: 2.2 litres of fresh milk and 450 g of white sugar gives 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, Ly and Huynh, 1992). An important feature in this category is informal milk marketing.

These smallholder systems are common throughout the developing countries in Asia, sub-Saharan Africa (SSA) and Latin America. The main difference in these situations is whether the systems are pasture-based as in most parts of Latin America and sub-Saharan Africa, or if dairy production is part and parcel of crop-animal systems such as in Asia. In SSA, the three main systems are pastoralists, agro-pastoralists and crop-livestock systems, representing a descending scale of cattle wealth and potential for milk production (Walsh et al., 1991). The first system is common in for example in Kenya and the second is common throughout sub-humid West Africa. Milk production from smallholder crop-animal systems are also common in the highlands of Kenya, Tanzania and Ethiopia.

One important feature 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 with this enterprise, and with it, expansion in the geographical areas that constitute smallholder limits. Good examples of this are Kathmandu in Nepal, Colombo in Sri Lanka, 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 in the city in the mid-1980s, but has now expanded to over twice this radius.

2. Smallholder cooperative dairy production systems

These systems are more advanced and mature, in comparison to the first. It is formed from a natural aggregation and concentration of smallholder dairy units, and because of this trend, is naturally larger involving anything from 40-250 smallholders. This kind of commercial smallholder dairying in growing rapidly around major cities. The cooperatives are focal points to provide services to farmers as well as promote organised collection, handling and sale of milk to consumers. Cooperatives enable improving their competitive edge in open-market economies. Good examples of this system are found in Bangkok, Karachi, Lahore and Rawalpindi in Pakistan and Bombay in India.

Two examples of this category are instructive. The first in The Nang Pho Dairy Cooperate, Ratchaburi Province, about 100 km south of Bangkok in Thailand. A survey of 43 farms indicated that 95% of them were less than 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 additional land mainly rented or owned, to grow fodders. Cattle sheds are mostly attached to the house or are 2-5 m from the house. The net cash return as percentage of total income was 68.9% and the average cost of production was US$ 0.22/kg (Skunmun and Chantalakhana, 2000). The authors suggest that attention to the following areas can further reduce the cost of production: feeds, reducing the number of herd replacements and maintenance of production records. It is interesting to note that from just dairy operations alone, only three farms made profits, emphasizing the importance of crop-animal systems and also the scale of operations.

Another example, a much large category, is the Landhi cattle colony in Karachi, Pakistan, which has about 220,000 animals in a 5 km radius. About 95% of these animals are buffaloes and 5% are cattle of which half are cross-breds. It began originally as a mechanism to concentrate animals outside the city limits, but this has grown into a large and complex enterprise within the city. Pregnant animals are purchased from rural areas, and completely stall-fed on cereal straws, green fodders and concentrates. After calving, female calves are sold except for a small number, which are kept as replacements for breeding while male calves are fattened for four months and slaughtered. At the end of their lactations, females are also slaughtered. Indiscriminate growth of the colony, without regulatory and policy interventions, has resulted 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 impacts on the environment.

In India, dairy production involving buffalo and cross-bred cattle is the major thrust in animal production, involving mainly smallholder systems in very well-organised dairy operations. The most outstanding example of this is 'Operation Flood' managed by the National Dairy Development Board (NDDB) which has used an integrated approach to production, procurement, processing and marketing of milk along cooperative lines. This is reflected in a 4-7% annual rate of growth in milk production, 70 million tones of milk produced in 1997, benefits to over 70 millions member households, increased urban consumption, and use of about 90% of indigenous dairy equipment. The beneficiaries include 60% of the landless and small farmers for whom increased milk production and income has enabled children to go to school (Patel, 1998). In these systems, buffaloes and cattle are reared together by smallholders to combine the different butterfat contents.

It is pertinent to note that in collaboration with non-government organisations (NGO), there also exist about 6000 womens' dairy societies which have empowered women. This has impacted on decision-making by women, use of daily income from the sale of milk, improved nutrition, and more stable households. Currently there exist 64,000 milk cooperatives supplying 14% of the total volume of milk produced in India (Mathur, 2000).

The development of similar cooperative dairy schemes are also common elsewhere, fanned by the success of 'Operation Flood' in India. In Bangladesh, cooperative development was initiated by a social worker, and today there exists some 345 cooperatives involving 925 villages. In Sri Lanka, dairying involves about 265 cooperatives spread across the country. In Kenya, smallholders produce 80% of the overall milk production, which comes mainly from the Rift Valley and Central Province, and there exists about 200 dairy cooperatives. However, due to economic reforms and liberalization of trade, marketing channels have diversified, resulting in a larger proportion of direct sales to private and institutional consumers (Staal et al., 1997).

3. Intensive dairy production systems

The third category of smallholder dairying is intensive production systems. The expansion of smallholder dairy production, coupled to open-market opportunities has led to the development of more intensive production systems. This trend is reflected in table 2, which shows that small and marginal farms,

Table 2. Distribution of dairy animals and milk production amongst 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

(de Jong, 1996)

and medium and large farms contributed 42% and 35% of the volume of the total milk produced. It is also pertinent to note that out of India's 105 million farms, 67% of these were milk producers who an average produced 2.5 kg/day.

These relatively larger and intensive systems are characterized by the following features:

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

Within smallholder dairy systems however, intensive dairy production units are numerically the smallest in numbers 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:

- The systems are very common in peri-urban areas and are distinctly market-oriented.
- The systems are a component of integrated crop-animal production systems.
- With the exception of countries in South Asia where buffaloes are used mainly for milk production, elsewhere in all other countries, Holstein-Friesian cattle and their cross-breds are used widely. In the Philippines, swamp × river buffalo cross-breds are used for milk production.
- The level of exotic blood is highly variable and about 25-75% on-farm. In general, the cross-breeding programmes have not been sustainable, including production and use of stable cross-breds.
- Short-term productivity gains from cross-breds are considered to be more important than the rational use of indigenous breeds and maximization of their production though selection.
- The choice of buffaloes and cattle for milk production is dependent on location as well as availability of animals.
- Dairy goats are also important throughout South Asia, East Africa, Central America and Vietnam in smallholder agriculture to supply precious animal proteins for household nutrition.
- There appears to be little or no data on the efficiencies of milk production between indigenous buffaloes and cattle, cattle cross-breds and also goats in smallholder systems.
- In socio-economic terms, dairying provides a most important means to generate daily income. This has important implications on human nutrition, participation of women, stable households and self-reliance.
- Increased interest in dairying, led by demand-driven processes is reflected in the expansion and intensification of smallholder production systems. However, there are emerging problems of milk handling, hygiene and environmental pollution.
- One concern about the trend to intensification is that smallholders may be unable to compete with the larger enterprises, because of the subsidies the latter enjoy. Removal of these subsidies provides better opportunities for the smallholders.
- Women and children are heavily involved in the milking and management of dairy animals.

Intensive smallholder dairy systems, mainly pasture-based, are common throughout Latin America and East Africa. In Costa Rica for example, intensive smallholder dairy systems are common in the lowland zone with high rainfall involving Brachiaria and Cynodon pastures and high stocking rates (Holman et al., 1995).

CONSTRAINTS TO PRODUCTION

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

1. Choice of species and breeds within-species and availability of animals for dairying
2. Feed resources and improved feeding systems
3. Improved breeding, production and animal health care
4. Management of animal manure and urine
5. Organized marketing and market outlets

It is not intended to discuss these constraints to production in detail, but it is relevant to highlight some of the more important issues, because of their importance and need to overcome emerging problems.

1. Choice and availability of animals

Buffaloes and cattle are used for dairying with complementary advantages, but a more serious problem is the availability of animals. Often good quality Holstein-Friesian cross-breds are not available, and also

prohibitive of cost for small farmers to use, unless these are made available by government schemes. Programmes to sustain such availability are therefore essential. Many of the larger farms attempt to produce their own cross-breds mainly through artificial insemination (AI), but again there are problems associated with the scale and cost of such operations.

2. Feed resources and improved feeding systems

Feeding and nutrition has repeatedly been highlighted as the major constraint in animal production systems globally (ILRI, 1995) and also sub-regionally in South East Asia (Devendra et al., 1997) and South Asia (Devendra et al., 2000a). The significance of improved 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 further constrain production.

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

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

In many situations, long dry periods of between 4-7 months, such as in eastern islands of Indonesia, northeast Thailand, central Vietnam, many parts of China as also countries in South Asia, result in inadequate availability of feeds. What feeds that are available at this time are also of poor quality, which further exacerbate productivity by animals. In such environments, it is therefore very essential that all avenues of feed production be considered in which the main objective is to ensure the availability of maximum amounts of feeds for animals.

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

3. Improved animal health care

Improved animal health care is also very essential and imposes a serious source of loss. Diseases often rank, with the availability of feed resources and nutrition, as the most important constraint to production. A variety of disease affect the calf and milking cow, and in the more progressive farms efficient and preventive and treatment measures can overcome these. With smallholder farms however, the situation is more serious because of inadequate use, access to appropriate corrective measures, and resources.

4. Management of animal manure

The management of animal manure produced on-farm represents a major health hazard and the problems increase with increasing herd size on the farm. The problem is associated with a number of issues, quantity and quality of manure and urine produced, inadequate removal, frequency of removal, storage in proximity to where the excreta is produced, labour availability, methods used, 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 very serious problems to both animals and also to man. The human health hazards in intensive smallholder systems are much more serious than in realized, due to inadequate supervisory and sanitary measures. This is reflected in a report on an investigation on the effects of dairy wastes on water and soil resources in smallholder dairy systems in Thailand (Chantalakhana et al., 1998). They found that:

- Waste water from older established dairy barns and crowded farms constituted great risk to the environment because of the higher COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand) and presence of coli-form organisms.
- Both waste water and leaching from piled up and drying manure on bare and surfaces were implicated in ground water contamination.
- Waste water from dairy farms, well water and public water ways in the locality all provide evidence of cumulative problem associated with lack of effective waste management practices and are therefore critical sites for monitoring.
- Monitoring of wastewater can be based on relatively simple tests that correlate broadly with

more sophisticated chemical and biological tests.

5. Organized marketing and market outlets

The availability of a market pull, organised marketing and access to market outlets are important prerequisites for the distribution and sale of the milk produced. In the absence of these, prospects for promoting efficient milk production will always be vulnerable and a risk.

OPPORTUNITIES FOR IMPROVEMENT

1. Feed resources and improved feeding systems

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

- Feed availability and feeding systems
- Seasonality of production
- Basal roughage resource
- Supplements
- Access to these feeds
- Extent of use of feed resource from the farm

Associated with above, it is pertinent to note four important issues relevant to feeds and feeding:

- Ruminant production systems are unlikely to change in the foreseeable future. New proposed systems and returns from them would therefore have to be demonstrably superior and supported my massive 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 roughages, and also various leguminous forages as supplements.
- During the recent Asian economic crisis, the smallholder dairy farms that collapsed were those who were dependent on the use of imported feeds, notably maize and supplements.
- Good profits from dairy production systems accrue from those systems that use maximum indigenous materials, especially feeds. An approach to promote and maximize such use and self-reliance is therefore essential.
- 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, crop residues as well as strategic use of protein supplements.

2. All year round feeding systems

A parallel strategy concerning opportunities to increase feed availability is the objective of developing sustainable all year round feeding systems. In this quest, maximising feed production is essential and 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.

3. Priorities for use the crop residues

Given the range of crop residues available, priorities for their use is essential in prevailing animal production systems. Priorities for their use will depend on the quantities available, the 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 3 summarizes the three categories of crop residues, their nutrient potential and the animal species that make the best use of them. These aspects have been received (Devendra, 1997; Devendra, 2000a).

4. Management of animal manure and nutrient recycling

Crop production in the developing countries depend to a very large extent on the use of organic manure

Table 3. Priorities for 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, mineral	Pigs, chicken, ducks, ruminants (meal, 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 fiber, stovers)	Low-protein, very fibrous, bulky	Ruminants (meat, draught), camels, donkeys, horses (draught)

* Ruminants refer to buffaloes, cattle, goats and sheep. (Devendra, 1987)

from animals. Inorganic fertilizers are often too expensive or unavailable to farmers who wish to use these, which clearly emphasizes the importance of animals, the value of crop-animal integration and interactions, and contribution to sustainable agriculture. Organic materials have been widely and beneficially use as soil amendments to improve soil fertility and crop yield. In northeast 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 to include soil structure and nutrient availability, increases infiltration and water retention capacity, and stimulate nitrogen fixing soil bacteria (Turner, 1995). Additionally, the humus in the dung improves soils pH, and therefore, phosphorous release. Farmers often use a combination of inorganic fertilizers and organic materials, for reasons of cost, to improve soil organic matter and soil fertility.

The availability of considerable quantities of underutilized and inefficiently used animal manure and urine in smallholder dairy units represent therefore a major challenge for their improved use to increase agricultural productivity.

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. Much 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 been seldom adopted. A lack of farming systems perspective has meant that important interactions between nutrition, genotype and disease and between animals and crop production have not been considered together, given that most dairy animals are found in mixed farms. Socio-economic and policy factors that influence the dynamics of the systems have also not been addressed.

1. Specific areas

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

(a) Recognition that dairy activities involve the totality of production-to-consumption systems.
(b) Better understanding of socio-economic factors influencing the dynamics of the systems.
(c) Study of the effects of specific improvements and components of the systems with maximum potential for intervention.
(d) Synchronization of feed availability and quality with the physiological and productive needs of different species (buffalo, cattle) and genotype (unimproved, improved) of dairy animals throughout the year.
(e) Studies on genotype × nutrition × disease interactions and the effect of animal health interventions.
(f) Study of the effects of improved nutrient flows and recycling on crop yields and crop residue quality in mixed farming systems.
(g) Developments of strategies for more efficient feeding of animals and nutrient recycling through the introduction of legumes into cropping patterns.

Addressing these and other issues call for a more holistic focus involving interdisciplinary approaches that together can be brought to bear the desired results in a cost-effective manner.

2. 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, smallholder and urban areas. The daily production, processing, and consumption of milk has promoted this linkage 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 artificial insemination, and drugs are examples that are concerned with this process. This movement and activities increase with decreasing proximity to markets in heri-urban areas, and the development is further encouraged with the presence of cooperatives that provide the necessary services and ensure returns to farmers.

One other opportunity for further potential expansion concerns the use of rain-fed areas. Currently, smallholder dairy production is mainly found in the irrigated areas where land is already overused, and potential opportunities exist for expanding their operations especially in rain-fed lowland area where soil moisture and crop production is relatively high. The justification for this approach, driven by the need for foods of animal origin, is associated with the following considerations in Asia (Devendra, 2000b):

- Available rain-fed area accounts for about 82% of the land area in Asia, found manly in the arid/semi-arid zones and also sub-humid zones (TAC, 1992, 1994)

- Within the rain-fed area, in the lowlands and uplands, there exists 51-55% of the total population of cattle and small ruminants in Asia
- Within the 86% of the total human population in Asia found in these areas, poverty and poorest of the poor are found here.
- Natural resource degradation is intense, and
- Major challenges exist for integrated natural resource management, poverty alleviation, and improved food security.

More importantly, such an expansion and the associated aspects of need for more productive animals, feed production, nutrient transfer and their collective use in smallholder dairy systems provide major opportunities to link rural and smallholder areas which will especially benefit resource-poor farmers. Integrated management of the natural resources will be more prominent, which will also address FAO's concept of area-wide integration. The promotion of linkages between rural and smallholder areas in the use of production inputs, intensification, nutrient flows, and marketing of produce need to be pursued in a manner that the activities are compatible with reduced pollution and minimal disease risks and human health issues.

One example of how a feed in rural areas can be processed, then fed to animals, and the manure is processed for crop cultivation, linking rural and smallholder areas, concerns a plant in Jakenan, Solo in Indonesia. Rice straw is bought from farmers at 30,000 Rups per truck, subject to microbial treatment and then fed to animals at the rate of about 3.5 kg of straw plus 3 kg of groundnut straw per head per day in a stall feeding systems. The animals used are Holstein-Friesian cross-breds, which gave 0.7-0.8 kg live weight increase per day. Each produced about 15-25 kg dung per day, and some 1,000 kg of processed manure (PM) is produced each month. The dung produced is removed from the barns every fortnight. The systems of production are in stages, from calves to adults. The wet dung is dried at 60℃, regularly stored, and bagged. This process evidently destroys all the residual toxins, weed seeds, microorganisms and render a fine product. This is sold at 300 Rups/bag. About 250 tons of PM is sold every month. The chemical composition of PM is 80%=OM, total N=1.5%, P_2O_5=1.6%, K_2O=1.8%, pH 5.5-7.5, CaO>2.8%, and Mg>0,5. The work is impressive, has expanded, and essentially involves three approaches:

1. Farmer purchase PM from the plant.
2. Straw and durg is collected from farms by the plant.
3. Plant helps farmers to process the PM on the farm for direct use.

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 have been recorded for tobacco and vegetables.

Attempts have been made to mix the PM with poultry manure in a 3:1 ratio, and in integrated systems involving dairy-fish operations. The returns to total income are 40% from PM, 30% dairying, 20% from sale of calves and 10% from fish.

This scheme is impressive and has been expanded to involve several parts of Central, East and West Java, Sulawesi and Riau, in which farmers have significantly benefited in terms of increased each income from the use of PM.

SUSTAINABILITY

Smallholder systems are in general constrained by numerous problems and include access to services, credit and resources so much so that strategies to cope with these through diversification of resource use and other ways represents the principal objective in subsistence systems. Over time however, both specialization, intensification, and increased income enable expansion of their operations especially among the more innovative and progressive farmers. Whether or not the systems are sustainable will depend to a very large extent 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 so relevant to market-oriented smallholder dairy production. It is essential that such a strategy 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 though crop-animal interactions, e.g. nutrient recycling
- No evidence of resource degradation. e.g. soil fertility
- Promotes maximum use of indigenous materials and a high degree of self-reliance.
- Maximizes the use of available labour and also creates employment opportunities, and
- Improved livelihoods of the rural poor.

PERFORMANCE INDICATORS

The multidisciplinary approaches, coupled to integrated natural resource management need to be identified with ensuring 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, coupled with methodologies for efficiency of resource use, appropriate technology interventions and increased 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 farmer are the target beneficiaries to whom the ultimate benefits need to be translated into improved livelihoods of the resource-poor.

Performance indicators reflect to a very large extent the success of the programme, hand in hand with economic analysis. An attempt is made in table 4 to suggest some performance indicators appropriate to developing country situations, with no claims to being exhaustive.

Table 4 summarizes possible performance indicators under three categories. The efficiency and management of integrated natural resources will largely determine animal performance and productivity, profitability and impact on stable households, improved livelihoods and rural development. Thus for example, excessive use of purchased feeds and concentrates will result in high feed cost as percentage of total cost, and implies in practice that maximum use need 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 increase crop yields with increased feeds for animals.

Table 4. Some performance indicators

Type	Indicator
1. Natural resources	- Increase 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 percentage of total cost of production - Return on assets - Change in net worth - Cash surplus
3. Households	- No. of children going to school - Malnutrition/human health - Extent of off-farm work - Stability of cooperation/revolving funds

CONCLUSIONS

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

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