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DAIRY PRODUCTION SYSTEMS IN THE TROPICS: A REVIEW

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DAIRY PRODUCTION SYSTEMS IN THE TROPICS: A REVIEW

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1.1 INTRODUCTION

Ruminant livestock are a major component of agricultural systems in tropical countries. In smallholder systems, which dominate tropical agriculture, ruminants are important because they produce much more than food: they provide direct cash income; they are capital assets; they produce manure for use as fertiliser and fuel; and they may be a source of power for transport and cultivation. Nevertheless one function, the production of milk for human food, is often the primary reason for keeping livestock, whether by pastoralists to meet their subsistence needs in arid and semi-arid regions, or by peri-urban smallholder farmers as a source of income from milk sales.

Dairy production is a biologically efficient system that converts large quantities of roughage, the most abundant feed in the tropics, to milk, the most nutritious food known to man. As Walshe *et al.* (1991) pointed out, where there is access to a market, dairying is preferred to meat production since it makes more efficient use of feed resources and provides a regular income to the producer. It is also more labour intensive and supports substantial employment in production, processing and marketing. Higher levels of production than those achieved in traditional tropical systems, whether from buffaloes, cattle, camels or small ruminants, often require the introduction of specialised dairy breeds and increased levels of inputs (nutrition and health care) and good linkages to markets, both for milk sales and input acquisition. Thus, the intensification of smallholder livestock systems through the adoption of dairy production is generally concentrated in areas with good infrastructure close to major markets, although less intensive production may occur in other, more distant areas (Walshe *et al.*, 1991). These market factors, therefore, play a major part in determining the type of dairy production systems found in the tropics, and they are particularly important influences on smallholder dairy development.

The challenge represented by the expanding demand for milk and dairy products in tropical countries is great, and the resultant opportunities for smallholders are large. The world's human population is expected to increase from 5.4 billion in 1990 to approximately 7.2 billion in 2010. Most of the increase will be in tropical developing countries, where there will be a marked shift from rural areas to urban centres, with major shifts in patterns of food production, marketing and consumption. In Latin America and the Caribbean (LAC), for example, total milk production has increased by approximately 2% per year since 1976, yet it has failed to keep up with human population growth. Tropical LAC produced 88% of its milk requirements during 1984-1991; by the year 2000 it is estimated that the deficit will be 9 million tonnes (Seré, 1990).

The lag in the domestic supply of milk relative to demand in the tropics has resulted from several factors. On the demand side, rapid increases in per caput income, especially in Southeast Asia, urbanisation and high income elasticities of demand have fuelled increases in per caput consumption. On the supply side, low animal productivity, inappropriate technologies, inadequate research and extension support, poor infrastructure and unfavourable external conditions have contributed to the poor performance of the livestock sector in general, and of the dairy sub-sector in particular (Williams *et al.*, 1995). Until recently many national policies made imported dairy products more available and affordable than domestically produced equivalents, but structural adjustment programmes in, for example, sub-Saharan Africa, have improved the incentives for domestic agricultural and dairy production (Staal *et al.*, 1997b).

Despite these changes, the volume of global milk output has not changed markedly over recent years because of counterbalancing forces: the substantial growth in milk output in Asia, Latin America and Oceania has been offset by a steep decline in output in eastern Europe and the former USSR (Griffin, 1997). During the next ten years, strong growth of milk production is expected in Asia and Latin America, where consumption is growing fastest, with global trends resulting in a shift in the balance of milk production away from developed to the developing countries. By 2000, developing countries are expected to account for 40% of world milk production, a share which is expected to grow further (Griffin, 1997). This shift will increase the importance of milk other than that from cows; while 99% of the milk output of the developed countries comes from cows, almost one third of milk production in the developing countries comes from buffaloes, goats, camels and sheep. Buffalo milk, for example, accounts for approximately half of the 67 million tonnes of milk produced in India (Aneja and Puri, 1997).

The increased demand for milk and dairy products in the tropics, where low-income groups dominate the market, is expected to favour the informal market, particularly where milk is produced primarily by small- and medium-scale producers. In all such regions, the success of the informal market is based on consumer reluctance to pay the extra costs of pasteurisation and packaging. In Nicaragua, for example, the modern processing sector handles less than 40% of total milk production; the remainder is marketed through the informal sector where approximately half is sold as unprocessed milk, 40% is used for cheese and the rest mainly for cream, butter and fermented milk. The informal sector is growing more quickly because of the higher returns if the farmer produces cheese on the farm or sells milk to vendors or small-scale processors (Anon., 1997).

In general, therefore, dairy production systems in the tropics are concentrated near consumption centres and it is no coincidence that cattle and rural human population densities are highly correlated (Kruska *et al.*, 1997), with specialised smallholder (and large scale) dairy farms generally located close to (peri-urban) or within (intra-urban) major markets, or more distant when there is an efficient market infrastructure. On the other hand, the systems of production and their productivity are influenced by agro-ecological factors and traditional consumption habits.

1.2 GLOBAL OVERVIEW OF TROPICAL DAIRY PRODUCTION

About two thirds of the world's cattle, almost all buffalo (97%) and half of all sheep and goats are found in the tropical zones of Africa, Asia and America, regions which support 70% of the world human population. Three quarters of the 3.9 billion people in the tropics live in Asia (Table 1.1).

Table 1.1 Livestock, milk and people in tropical Africa (SSA), Asia and Central and South America (CSA)

	SSA	Asia	CSA	Total (Mean)
Bovines, m[a]	165	509	329	1003
AU, m[b]	92	240	262	594
Milk, m tonnes	13.2	91.9	44.2	149.3
Milk, kg AU^{-1}	143	382	168	(251)
People, m	519	2886	457	3862
Milk, kg $caput^{-1}$ yr^{-1}	25	32	97	(39)

Source: Seré *et al.*, 1996

[a]bovine = cattle and buffalo; [b]AU = animal unit equals 400 kg LW

Livestock production in the three continents differs in many respects, mainly due to human population density. Compared to Asia, sub-Saharan Africa (SSA) and Central and South America (CSA) have relatively low population densities. Agricultural land (grazing and cropland) is 1.6 ha $caput^{-1}$, while in Asia it is 0.3 ha (Table 1.2). Livestock wealth shows a different trend, ranging from 0.08 animal units (AU of 400 kg LW) $caput^{-1}$ in Asia to 0.18 and 0.57 in SSA and CSA, respectively. Conversely, agricultural land available per AU in SSA is 2.5-3.5 times higher than in Asia and CSA, mainly because in the latter the quantities of feed ha^{-1} from rain-fed and irrigated cropland (in Asia) and sown pastures (in CSA) are much higher than from the natural range-lands in SSA (Winrock, 1992), which provide over 80% of the total livestock feed in Africa (Table 1.2).

Table 1.2 Land, livestock and people in tropical Africa (SSA), Asia and Central and South America (CSA)

	SSA	Asia	CSA	Total
Grazing, m ha	745	561	587	1843
Crops, m ha	127	358	131	616
Ha AU^{-1}	9.5	3.8	2.7	4.1
Ha $caput^{-1}$	1.68	0.32	1.57	0.6

Source: Seré *et al.*, 1996

These land endowments impact on milk production. In 1993-4, the tropics produced 150 million tonnes of milk or 36% of the global output (Seré *et al.*, 1996). In SSA, three quarters of the milk is produced by cattle, the remainder coming from camels - mainly in the arid zone - and goats (Walshe *et al.*, 1991). In Asia, cattle account for 47% of all milk, with most of the remainder produced by buffalo. In CSA, almost all milk is produced by cattle.

The interplay between people, livestock and land (Tables 1.1, 1.2) has resulted in variable availability of milk. In Africa and Asia, there is about 30 kg caput^{-1} yr^{-1}, one third as much as in CSA (Table 1.1). Milk yields averaged about 60 kg per 100 kg of livestock mass maintained, ranging from 36 kg in SSA to 95 kg in Asia (Table 1.1). The latter is one tenth of the efficiency in the OECD countries (950 kg AU^{-1}), where the average dairy cow produces 5100 kg milk yr^{-1}, compared to 340, 900 and 1100 kg per cow milked in SSA, Asia and CSA, respectively.

Sub-Saharan Africa

As shown in Table 1.1, milk output per AU and per caput in SSA is lower than in Asia and America, despite a stocking rate of only 0.1 AU ha^{-1} of agricultural land. Milk output is lowest in the subhumid/humid zone because livestock wealth per caput is low, fewer cows and goats are milked and offtake per cow is lower than in the other zones (Table 1.3). The highlands of SSA are the most productive in terms of milk ha^{-1}, but production per head of cattle is lower than in the dry zone (70 vs 58 kg); this is because the majority of cattle are found in the Ethiopian highlands, where male stock used for traction comprise a high fraction of the herd. However, in the densely populated highlands of Kenya, and to a lesser extent in Tanzania, milk production has risen rapidly due to the widespread adoption of intensive dairy production with crossbred or high grade cows.

Table 1.3 Livestock, land and milk production in arid/semi-arid (A/SA), subhumid/humid (SH/H) and highland (HL) sub-Saharan Africa

	A/SA	SH/H	HL
AU caput^{-1}	0.26	0.10	0.25
Grazing, ha AU^{-1}	10.1	7.4	4.6
Crops, ha AU^{-1}	1.1	2.3	0.8
Milk			
▪ Kg AU^{-1}	191	76	135
▪ Kg caput^{-1}	49	8	34
▪ Kg ha^{-1}	17	10	25

Source: Seré *et al.*, 1996.

These zonal differences in production systems reflect - at least in part - dietary and cattle keeping habits of the local population. Whereas in the dry zones and the highlands, cattle keeping and milk consumption has been a long tradition, in the more humid zones cattle keeping has been constrained by tick-borne diseases and trypanosomosis, resulting in a predominance of sheep and goats and minimal dairy production.

Asia

The three major agricultural systems in tropical Asia - pasture-based, rain-fed and irrigated crop-livestock - support three quarters of the human population in the tropics or just over half the global human population of 5.5 billion (Table 1.1). The extensive agro-pastoral system is well-endowed with grazing land, covering 70% of the total. Milk production is low (Table 1.4), because livestock are primarily kept for meat, with its beef production accounting for 15% of Asia's total output.

The proportion of irrigated land distinguishes the other two production systems. In tropical Asia, in sharp contrast to sub-Saharan Africa, about a quarter of the cropland is irrigated, with approximately 20% in the "rain-fed" group and 50% in the "irrigated" systems. The two systems are distributed similarly across eco-zones: 50% in the semi-arid, 35% in the humid zone and 15% in the highlands, and support 2.6 billion people, two-thirds of whom are associated with the high-irrigation system (Table 1.4). Livestock and land capital is greater in the rain-fed system, resulting in higher milk availability per caput, and higher milk yields of cattle and buffalo per AU.

Table 1.4 Livestock and milk production in three major agricultural systems in tropical Asia

	Pasture based	Rain-fed Crop-livestock	Irrigated Crop-livestock
AU caput^{-1}	0.09	0.11	0.08
▪ Cattle	0.14	0.17	0.11
▪ Buffalo	-	0.07	0.05
Grazing, ha AU^{-1}	16.7	0.8	0.8
Cropland, ha AU^{-1}	0.7	1.6	1.3
Milk			
▪ Kg AU	20	509	324
▪ Kg ha^{-1}	1	211	155
▪ Kg caput^{-1}	2	56	24

Source: Seré *et al.*, 1996

In Asia, as elsewhere, the development of dairy production systems is strongly driven by cultural preferences and their market forces. As a result, India and Pakistan, at 75 kg milk caput^{-1}yr^{-1}, contribute 96% of all the milk produced in tropical Asia. By contrast, in SE Asia, where 550 mill. people consume on average 12 kg caput^{-1}yr^{-1}, in 1995 two thirds was imported; milk production from local cattle and buffalo is low and dairy systems, as yet, are relatively unimportant.

Central and South America

In Central and South America (CSA) livestock systems can be grouped by eco-zone for the semi-arid and the highland regions, and by production system (pasture-based or crop-livestock) in the humid zone; the latter are the most important as they include 70% of all cattle and two thirds of the land (Table 1.5). Yet, because of the relatively low population density, they include only half of CSA's 456 mill. people (Table 1.1). The contrast between the two humid zone systems is evident, with livestock capital and milk production much higher in crop-livestock systems (Table 1.5). Output ratios as a proportion of total milk and meat are 20:42 percent in the pasture-based and 25:22 percent for the crop-livestock systems, where productivity per unit of land is four times as high. Livestock in the highlands (mainly the Andean chain of mountains) are found in pasture-based production systems at high altitude (>2700 m a.s.l.) merging into crop-livestock systems at lower altitudes and in valleys. These systems are diversifying into cash crops (Quiroz *et al*, 1997), explaining the high arable/grazing land ratio.

In the semi-arid zone, mainly concentrated in NE Brazil, arable land in the pasture-based and crop-livestock systems comprises only 3% of the total land, a quarter of which is irrigated. In terms of livestock output, this region is the least important, as it supports 15% of all cattle and produces only 17% of total milk of the region.

Table 1.5 Land, cattle, milk and people in Central and South America

		Humid		
	Semi-arid	Pasture	Crop-liv.	Highlands
AU caput^{-1}	0.37	1.54	0.50	0.28
Cattle caput^{-1}	0.45	1.95	0.65	0.35
Grazing ha AU^{-1}	2.7	2.6	1.1	2.1
Arable ha AU^{-1}	0.2	0.4	0.4	0.5
Milk				
• Kg AU^{-1}	191	87	273	237
• Kg ha^{-1}	55	29	118	73
• Kg caput^{-1}	71	135	118	68

Source: Seré *et al.*, 1996

1.3 DAIRY PRODUCTION SYSTEMS IN SUB-SAHARAN AFRICA

Milk production in sub-Saharan Africa amounted to 1.27 m tonnes in 1988, of which three-quarters was produced in East Africa. Cow milk accounted for 80% overall, but only half of the milk produced in East and West Africa, and nearly 100% in Central and Southern Africa. Output TLU^{-1} (250 kg LW) averaged 70 kg yr^{-1}, being more than twice as high in East Africa as in the other regions due to the high yield (78 kg hd^{-1}) of local cattle in the Sudan and the contribution of intensive dairy production systems in Kenya (Staal *et al.*, 1997b).

Table 1.6 Annual milk supply (kg per caput) and percentage from domestic sources by region in sub-Saharan Africa in 1988

Region	West	Central	East	Southern	All
Kg caput^{-1} Y^{-r}	13.2	9.2	56.1	19.2	26.5
% domestic	61	52	96	68	84

Source: Walshe et al., 1991

Self-sufficiency levels varied (Table 1.6); in West Africa, levels in Sahelian countries were high (60-70%) and low in coastal countries with large cities along the seaboard (8-50%). In contrast, all countries in East Africa were relying on local sources (>90%), whereas in Central and Southern Africa, imports ranged from 75% in Rwanda and Burundi to <10% in Zaire and Zimbabwe.

There are three major land-based systems producing milk in SSA, pastoralists, agro-pastoralists and crop-livestock farmers (Walshe *et al.*, 1991), representing a descending scale of cattle wealth and therefore potential milk off-take. Household demand and market access determines actual off-take, which ranges from near zero to 500 kg per lactation (de Leeuw and Thorpe, 1996). Thus market participation and cattle density are the main determinants of milk supply, which varies from 2,500 to

only 80 kg km^{-2}, the latter in areas where farmers rarely milk their cows and/or cattle density is low. However, supplies rise to 64 tonnes milk km^{-2} in the densely populated highlands of Kenya, where farmers keep high-grade dairy cattle producing 820 kg $head^{-1}$ $year^{-1}$ (Peeler and Omore, 1997) (Table 1.7).

Table 1.7 Characteristics of milk production in selected farming systems in sub-Saharan Africa

	(Agro-) pastoralists			Crop-livestock		
	Kenya	Gambia	Nigeria	Zimbabwe	Guinea Bissau	Kenya
Cattle density, head km^{-2}	35	30	32	15	10	78
Milk, kg $head^{-1}$ of cattle	44	85	44	25	8	820
Milk, tonnes km^{-2}	1.54	2.55	1.41	0.38	0.08	63
Rural people per km^{-2}	5	80	70	29	21	322
Milk, kg $caput^{-1}$ yr^{-1}	308	32	20	13	4	197

Sources: see text

An example of pastoralist systems is that practised by the Maasai in the sparsely populated semi-arid range-lands of Kenya (Table 1.7). The Maasai live in extended families (10-15 people) with herds averaging 100-170 cattle and as many sheep and goats (Bekure *et al.*, 1991). They produce and consume about 0.85 kg of milk per person per day, while the sale of livestock is the main source of income. As few grow crops, most foodstuffs are purchased. Milk surplus is shared with neighbours or exchanged in barter, but is rarely sold except by households living close (<5 km) to main roads and urban centres where there is demand for fresh and fermented milk, and butter. Similar pastoral systems are found in Southern Ethiopia; working among the Borana, Holden and Coppock (1992) reported that frequency and amounts of dairy products traded depended on herd size and distance to the market: butter replacing liquid milk with increasing distance and women from households with large herds trading more often. Butter was sold to lorry drivers and bus passengers en route to Addis Ababa, some 500 km away.

A contrasting pastoral system is practised in the Gambia by herders, pastoralists who act as managers of communal herds, the cattle of which are entrusted to them by local farmers who each own a few head (Table 1.7). As sale of milk is the major part of the herder's income, cows and calves are well managed and milk off-take per cow is > 400 kg per lactation, or 40% above the yields in family herds of agro-pastoral Peuhl living in a similar environment (Itty *et al.*, 1993).

Increasing numbers of agro-pastoralists are found in sub-humid West Africa, where, for example, in Nigeria, small groups of Fulani live among indigenous smallholder farmers, who keep small ruminants rather than cattle. Most Fulani crop small fields of grain (1-2 ha), earning their living mostly from sales of milk and live animals, although in Côte d'Ivoire some have become settled farmers growing cotton as a cash crop (Itty *et al.*, 1994). Being the main supplier of milk in rural and often to urban areas, diverse trading patterns have evolved. In well-populated areas in Nigeria, for instance (Table 1.7), Fulani women head-load 3-5 kg of milk to nearby villages, home

delivering milk to their regular customers, and selling any remainder on the local market at distances of 2-10 km (Waters-Bayer, 1988). Depending on transport infrastructure, women may trade larger quantities, usually bulking up from neighbours and friends.

Although milk is an important subsistence output of many smallholder crop-livestock systems, it is rarely traded, hence the milk supply caput^{-1} and km^{-2} are much lower (Table 1.7). Typical of these systems, termed mixed-farming by Walshe *et al* (1991), are the communal farming areas of Zimbabwe (Steinfeld, 1986) and similar systems in West Africa (e.g. Guinea Bissau: Picaos-Goncalves, 1995), where farms and herds are small (1-5 ha, 5-10 cattle), and cattle are used for traction, subsistence milk and manure (Table 1.7).

In the peri-urban areas around larger cities, production and marketing systems are more complex. For example, milk to Bamako, the capital of Mali, is supplied by two types of producers: high-input large scale dairies using crossbred cattle close to the town, and peri-urban (within 25-40 km) communal dairies producing milk from herds of local cattle assembled from several owners (Achuonjei and Debrah, 1992). Many of the large-scale owners (herds of up to 200) delivered milk directly to the co-operative processing plant to be added to imported reconstituted milk. Others, selling directly to consumers, accounted for half of the informally marketed milk; the rest was delivered to consumers through one to three intermediaries. Similar peri- and intra-urban production systems operate in Addis Ababa, Ethiopia (Staal, 1995), where over 70% of milk was sold directly to consumers mainly from small land-less dairy enterprises located within the city (Debrah, 1992). The remainder was sold through itinerant traders, small shops, kiosks and larger grocery stores.

When smallholder crop-livestock systems are supported by market infrastructure, dairy can become a major component, especially as systems intensify in the face of increasing human population pressure. In the densely populated Kenya highlands (Table 1.7), after independence milk production shifted from large-scale herds to smallholder crop-livestock farms, which also grew coffee and tea, and vegetables and fruit closer to the urban centres (Tiffen *et al.*, 1994). Hence, the milk enterprise became integrated into multipurpose farming systems, relying on cash crops, maize and beans, supported by off-farm income from towns through the extended family network. Farms are frequently 1-2 ha with 1-2 cows (generally Holstein Friesian or Ayrshire) comprising 50% of the herd, the other half consisting of female calves and heifers. Feeding is mainly cut-and-carry with planted Napier grass (*Pennisetum purpureum*) and crop residues, especially from maize and bananas (Staal *et al.*, 1997a). On average total daily milk output is 10 kg per farm, of which a quarter is for home consumption and the rest sold. In the late 1980s, sales were mainly through local dairy co-operative societies, with some to neighbours, but since economic reforms and liberalisation of trade, marketing channels have diversified, with a larger proportion of direct sales to private and institutional consumers (Staal *et al.*, 1997b).

Characteristic of tropical regions with good market access, the development of smallholder dairy systems in the Kenya highlands is marked by three elements:

declining farm size, upgrading into dairy breeds and an increasing reliance on purchased feeds, both concentrates and forage, resulting in milk yields per lactation increasing by as much as five times, while milk yield ha^{-1} of land planted with forage rose by a factor of 40 (de Jong, 1996).

Table 1.8 People, cattle and milk in Tanzania

Farming system	Livestock Extensive	Crop-livestock Semi-intensive	Livestock-crops Intensive
Scale, cattle HH^{-1}	55	6	4
Rural HHs, % of total;	10	86	4
Cattle, N x 10^3	7,800	7,500	246
Milk output, kg $hd^{-1}yr^{-1}$	28	45	764
Total milk, tonnes x 10^3	218	338	188

Source: Omore and Staal, 1998.

The range of systems found in sub-Saharan Africa is captured at a country level in Tanzania, which has some 15.5 m cattle distributed across three major systems producing milk (Table 1.8). It is estimated that there are 110,000 (agro-) pastoral households, who own and manage 7.8 million cattle, many of which are in large herds similar to those of the Maasai in Kenya (Table 1.7). Potential milk production is probably 55 kg milk $head^{-1}yr^{-1}$, but since milk is mainly used for subsistence, only half (28 kg) is actually extracted for human consumption, because households with large herds only exploit 20% of the yield potential (Grandin, 1993). In areas of higher rainfall, over 3 million crop-livestock farmers with smaller herds (5-8 head) form the largest production system, producing some 45% of milk nationally. They realise yields of 45 kg $hd^{-1}yr^{-1}$, which is closer to potential.

In the third system, in 1997 246,000 crossbred and high grade cows in 60,000 holdings produced 0.19 m t of milk (Omore and Staal, 1998). Over 70% of these dairy cattle are found in the small-scale intensive production system in the highlands and in peri-urban herds, the majority stall-feeding crop by-products and planted forage or harvested natural pasture. The remainder practise grazing of natural pastures, often supplemented with crop residues, some fodder and/or concentrate. There is significant intra-urban dairy production from small herds (often owned by civil servants) based on purchased forage or grazing public land. Larger herds, some grazing fenced paddocks, are found in the peri-urban areas.

In spite of their relatively small numbers, these dairy cattle contributed some 90% of all marketed milk. In 1997, about 90% of the marketed milk was delivered informally, either by direct sales to customers (60%) or through vendors (30%); the remainder was marketed by co-operatives and retailers (Omore and Staal, 1998). The very small contribution of the extensive and semi-intensive production to milk markets (10% of market flow from 98% of the animals) is indicative of the separation of these systems from the major urban consumption centres, and the inadequate market infrastructure to link them. This is further indicated by large price differentials between rural and urban areas, indicating relative deficit and surplus areas.

These production systems in Tanzania illustrate the principles common to dairy production in SSA: the potential to increase milk production from pastoralist and agro-pastoralist systems depends on the cost of collection and transport, particularly where distance-sensitive informal (raw milk) markets predominate. In turn, unit costs of the support services (input supply; animal health services; milk marketing) decrease as production increases (Walshe *et al.* 1991). Consequently, production systems nationally can become highly differentiated in structure of production and achievement of biological potential.

1.4 DAIRY PRODUCTION SYSTEMS IN ASIA

In tropical Asia, dairy production is concentrated in the rain-fed and irrigated crop-livestock systems of India, which account for most dairy cows and buffaloes and over 90% of all Asian milk production (Table 1.4). Milk production in India increased from 17 m tonnes in 1951 to 54 m tonnes in 1991 and is expected to rise to 86 m tonnes in 2000. The urban sector (28% of the population) consumed 56%, three times as much per caput as the rural population (Table 1.9). Per caput availability has increased to 72 kg per year, in part the result of 40 years of intensive dairy co-operative development under Operation Flood (Patel, 1997), as well as the growth of the larger private and informal markets. The exceptional emphasis on milk production is at least in part explained by religious beliefs forbidding slaughter and beef consumption.

Table 1.9 People and milk consumption in India in 1995

	People, m	Milk m tonnes	Consumption kg caput^{-1} yr^{-1}
Rural	660	29.2	47
Urban	254	37.1	148
Total/mean	914	66.3	72

Source: Aneja and Puri, 1997

India is also exceptional in that - despite this vast expansion of milk output - dairying is characterised by a predominance of small-scale producers farming little or no land, and a reliance on indigenous breeds of cattle and buffaloes; in 1996-7, crossbred dairy cattle were only 8% of the total; buffaloes produced 55% of all milk.

The contribution of buffalo to dairy production in part reflects a shift from their importance as traction animals in smallholder farming systems (Table 1.10). Herd structures and their changes between 1966 and 1987 reflect the increasing emphasis on dairy production. The percentage of females >3 years remained constant, but the proportion of cows in milk increased: from 45 to 49% for cattle and 50% to 60% for buffaloes.

Table 1.10 Composition of cattle and buffalo herds in India in 1966 and 1987

	Cattle		Buffalo	
	1966	1987	1966	1987
Total number, m	176	200	53	76
Cows > 3 yr, %	29.4	30.5	48.2	50.9
• In milk, %	11.9	14.9	24.4	31.2
• dry, %	17.5	15.6	23.8	20.4
Males > 3 yr, %	43.2	37.4	16.6	10.4
• working, %	40.0	36.6	13.8	6.8
• others, %	3.2	0.8	2.8	3.5
Young stock, %	27.3	31.5	35.2	38.7
Total, %	100	100	100	100

Source: Kurup, 1997

In 1991 59% of the farms were < 1 ha, 44% (46 m) of which were classified as land-less (Table 1.11). Together, these holdings comprised 15% of land under cultivation (Aneja and Puri, 1997). Out of India's 105 m farms, 60 m (67%) were milk producers who, on average, produced 2.5 kg d^{-1}. Whereas land is unequally distributed, dairy stock holdings are not, and neither are there large differences between milk yield per animal across the three groups of farmers (Table 1.11).

Table 1.11 Distribution of dairy animals and milk production amongst land-less, small/marginal and medium/large scale producers in India

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

Source: de Jong, 1996

In contrast to the grass-based dairy production systems in most of the tropics, in India milk is produced mainly from crop residues. Singh *et al.* (1997) show that two thirds of the available feed originated from cropped land, 25% of which is irrigated and often double cropped. Four percent of the cropped land is grown to forage crops providing another 12% of the total feed, while grazing supplies only 14% of all feed. The organised animal feed industry sector is small, but developing rapidly, producing 1.5 m t of cattle feed and 1.2 m t of poultry feed in 1995.

Unlike in India, the dairy production systems in Sri Lanka and in other parts of Asia mirror those seen in sub-Saharan Africa (section 1.3), ranging from indigenous cattle communally grazing relatively dry lowlands to intensive zero-grazing enterprises with cross-bred cows producing 1500 kg of milk per year (Table 1.12) and up to 11 tons of milk ha^{-1} of farmland.

Herd and farm size in Sri Lanka decline with altitude, but stocking rates per farm increase, implying an increasing use of off-farm feed sources, such as coconut plantations and forest gardens (Table 1.12). In the midlands and uplands, smallholder crop-livestock farmers are the major milk producers, many of whom added dairy to

their farming enterprise mix in the late 1970s, acquiring crossbred dairy cattle on credit (de Jong, 1996). Herds are small (mostly 2-3 head) but represent 3.5 TLU ha^{-1} of farmland, with cows comprising half of the total stock. Peak milk yields averaged 6.6 kg d^{-1} (2700 kg ha^{-1}), 4.1 kg d^{-1} of which were sold. Most of the crop land was occupied by tree crops (tea, coconuts, bananas, fruits) and vegetables, which provided 30% of the on-farm net income (but only 14% of total net income), crops and animals sales accounting for 57% and 13%, respectively.

Table 1.12 Characteristics of cattle production in smallholder farms in Sri Lanka

Grazing Systems		Kg ha^{-1}		Milk	Farm Size		Milk/Farm
Eco-zone	Feeds	Milk	Beef	kg cow^{-1} yr^{-1}	ha	Cows	kg d^{-1}
D - L	Communal land	1580	220	170	1.3	12.1	6.7
D - I		1840	105	270	1.5	10.2	4.7
I - L	Coconut	850	45	300	1.2	3.5	2.9
W - L	Plantations	3270	60	620	0.7	3.7	6.3
I - M	Forest Gardens	2080	35	940	0.8	1.7	5.3
Cut and Carry Systems							
Ecozone	**Feeds**						
I - U	Grasses	2040	35	1070	0.8	1.6	4.7
W - U	Browse	3130	50	1550	0.7	1.5	6.4
D - L		10970	310	1490	0.5	3.6	14.7

1) Rainfall: Dry (D): < 2000 mm; Intermediate (I): 2000-2500 mm; Wet (W): >2500 mm
2) Altitude: Lowland (L): <500 m; Mid-altitude (M): 500-1000 m; Upland (U): > 1000 m
Source: Adapted from de Jong, 1996.

Whereas dairy production is an integral part of smallholder agriculture and land-less livestock systems in south Asia, dairying is relatively unimportant in SE Asia, but is developing quickly in response to market demand. In Thailand, as with most SE Asian countries, milk was not part of the traditional diet prior to 1970. In 1954, the country was one of the poorest in the world, but between 1970 and 1990, the GNP $caput^{-1}$ quadrupled, and is expected to rise by another 50% by the year 2000.

Thailand has 7.2 m cattle and 4.7 m buffaloes, and the livestock share of the agricultural GNP is about 12%, with the pig and poultry industry being the most important (Danida, 1994). Ready-to-drink milk consumption took off in the mid-1970s reaching 40,000 tons in 1984, and 350,000 tons in 1993. Local fresh milk deliveries followed the same trend, increasing seven-fold between 1980 and 1993, supplying 19% of total consumption. Fresh milk was produced by about 150 dairy farmers in 1971, increasing in 1993 to 12,500 with a total of 48,000 cows, supplying 133,000 tons of milk (equivalent to 10.6 t per dairy farmer).

Table 1.13 Characteristics of dairy production systems by farm size in Thailand

	Farm size			
	Small	Medium	Large	Average
Farm size, ha	1.3	8.1	12.3	5.0
Total herd, head	29.0	20.6	22.7	25.1
Total cows	15.4	13.3	9.0	14.3
Cows in milk, %	74	58	64	71
Milk, kg $cow^{-1}yr^{-1}$	2254	1845	2303	2365
Milk sales, kg d^{-1}	95	67	88	92
Milk, t $ha^{-1}yr^{-1}$	27.4	3.1	2.8	6.9

Source: adapted from Danida, 1994

The characteristics of this rapidly expanding dairy production are summarised in Table 1.13 for three locations with increasing farm size. Herds were relatively large, generally Friesian-Holsteins and their crosses grazing fenced pastures, producing 2,000 kg milk cow^{-1} yr^{-1}. Concentrate feeding averaged 5-6 kg d^{-1} for cows in milk and 2 kg for dry cows. Feed costs were about 70% of total operating costs, the largest being expenditure on concentrates (65-80%). Over 30% of the sampled farmers sold more than 100 kg of milk per day and several had invested in milking machinery. Milk collection was privatised and fees amounted to 7-10% of the operating cost. In 1993, production from this high-input system was barely profitable, and it was recommended that dairy production should be better integrated with crop production, taking advantage of the benefits to whole farm productivity accruing to smallholder dairy producers in South Asia and East Africa.

In summary therefore, dairy production in Asia is dominated by the crop-based systems of India, where milk from buffaloes is increasingly important. The development of efficient dairy production in India, with substantial welfare benefits for millions of poor households, has resulted largely from the effective output/input market services provided by village-level co-operatives. Private sector (some informal) milk markets remain as important, however. As the demand for milk and dairy products increases in Asia, driven by urban consumers, especially in SE Asia, the lessons from India and Sri Lanka can play an important role in guiding the development of smallholder dairy systems in the region.

1.5 DAIRY PRODUCTION SYSTEMS IN LATIN AMERICA

Tropical America, despite its large ecological diversity, can be divided into two broad zones: the lowlands (<1000m asl) and the highlands (>1000m). The Andean mountain range divides the lowlands bordering the Atlantic Ocean in the east and those bordering the Pacific Ocean in the west. Two major dairy production systems have evolved: dual-purpose cattle enterprises in the lowlands, mainly of large and medium scale, and the smaller scale crop-livestock systems in the highlands. Generally, land is privately owned, feeds are derived mainly from sown pastures, and a large proportion of the milk and dairy products are marketed.

The evolution of the production systems in the lowlands has involved intensification from pure beef to dual-purpose beef-milk and eventually to milk-beef (Berry, 1985;

Wadsworth, 1992). Changes were most prominent in the tropical lowlands where large-scale enterprises predominate. The gradual shift followed progressive steps (see Box), the outcomes of which are quantified in terms of land use and beef and milk output per ha in Table 1.14.

Intensification of cattle production systems in Latin America

1. From beef to milk production

- From indigenous stock (Zebu, Criollo) to upgrading with dairy breeds
- Reducing calf weaning age
- From opportunistic short term milking to exploiting the entire lactation.
- From use of milk for household needs and limited cheese production to maximising daily sales of liquid milk
- Increased proportion of cows; sales restricted to weaned calves and culled cows
- Simultaneous specialisation of beef enterprises into outgrowing and fattening

2. Intensification of feeding systems

- Shift from natural pasture to sown grasses and grass/legume mixtures, leading to higher stocking rates
- Increased fertiliser use, rotational grazing and allocation of the best pastures to lactating cows
- Increased supplementary feeding of concentrates and agricultural by-products

Dual-purpose systems

In the large-scale dual-purpose systems, crossbred (mostly Holstein Friesian (HF) or Brown Swiss x zebu) cows are milked by hand and managed in pasture-based systems. Generally male calves are sold when weaned. Holmann *et al.* (1990) documented examples of these systems in the humid (rainfall 2900 mm) and dry lowlands (rainfall 1300 mm) of Venezuela:

- Farm size 285-950 ha; cows: 180-380 head
- Stocking rates, cows ha^{-1}: humid 0.70; dry 0.50
- Age of first calving: 30 months; calving rate: 0.73
- Milk yield: > 50% HF, 3500 kg cow yr^{-1}; 2.1 t ha^{-1}
  < 50% HF, 2650 kg cow yr^{-1}; 1.6 t ha^{-1}
- Income from milk about 75% of total
- Kg milk/kg conc. feed: humid 15; dry 5.5.

In terms of intensity of milk production, the ranches in Venezuela resemble the dual-purpose system in the SE of Mexico (Table 1.14), but in Venezuela, calving rates and milk yields were higher, the scale of operation much larger and stocking rates lower. Although the proportion of income from milk sales was similar, the outgrowing of male stock was less common in Mexico. These dual-purpose systems benefit from the ability to shift the emphasis of production between beef and milk, a flexibility reflected in incomes from milk ranging from 25% of 75% of the total (Wadsworth, 1992). Specialised beef production systems can be found side by side with dual-

purpose systems, as observed in the SE of Mexico where beef systems were in the majority (Anderson *et al*, 1992).

Table 1.14 Variables of beef, dual-purpose (DP) and dairy systems in Costa Rica and Mexico

	Beef[1]	DP[1]	DP[2]	Dairy[1]
Farm size, ha	74	43	28	35
LSU ha^{-1}	0.95	1.62	1.21	2.01
Milk, kg cow^{-1} yr^{-1}	220	560	1715	3490
Milk, t ha^{-1} yr^{-1}	0.10	0.46	1.26	3.48
Beef, kg LW ha^{-1} yr^{-1}	70	133	142	124
Milk income[3], %	32	53	75	95

[1]Data for Costa Rica (Wadsworth, 1992); LSU = one cow
[2]Intensive DP system in Yucatan (Mexico), from Anderson *et al.*, 1992
[3]Based on a live weight/milk price ratio of 3:1.

Intensive milk production

Intensive (or specialised) dairy systems of all scales occur in tropical America; the medium-scale dairy farms presented in Table 1.14 practise high stocking rates and achieve high milk yields per cow and per ha. Large-scale specialised dairy enterprises in the Venezuelan highlands manage pure Holstein cows yielding annually 5800 kg milk, with income from milk sales reaching 93% (de Jong, 1996). Feed comprised 77% of total costs, two third of which for purchased feed. Output of milk per ha was 12.2 t, higher than equivalent systems in Costa Rica (Table 1.14), in part due to the effects of the contrasting highland and lowland environments on the performance of pure Holstein cows (Holmann *et al.*, 1990).

In Costa Rica, intensive small-scale dairy farms in the lowland zone with high rainfall rely on planted pastures (*Brachiaria, Cynodon*) and high stocking rates (Table 1.15). Holmann *et al* (1995) reported that between their establishment in 1979-80 up to 1990, performance declined due to invasion of unpalatable low yielding grasses, exacerbated by low fertiliser inputs (Table 1.15). Combined with low levels of concentrate feeding, this led to a decline in milk yields and net incomes. Attempts to expand farm sizes and diversify back into beef production did not stem the loss of income, illustrating the importance of skilled management for efficient and profitable dairy production, especially in intensive systems.

In common with East Africa and South Asia, small-scale intensive crop-dairy systems have developed in the sub-tropical highlands (1200-2700 m) of Central and South America where rainfall varies between 1600 to 2800 mm and falls 7 to 12 mo of the year. Many of the soils are volcanic and fertile, and coffee is a major cash crop (Quiroz *et al.*, 1997). As human population densities are, as yet, lower than in parts of East Africa, the systems are still largely pasture-based, often in rotation with

Table 1.15 Changes in the performance of smallholder dairy farms at two sites in the lowlands of Costa Rica, 1980 to 1990

	Rio Frio		*Somafluca*	
	1980	**1990**	**1980**	**1990**
Farm size, ha	10.6	17.6	10.1	12.8
% pasture	91	91	99	83
Stocking rate, AU ha^{-1}	1.9	1.9	2.5	2.6
Total herd, AU.	18.3	31.3	23.4	31.2
Cows, head	15.6	21.6	19.6	19.7
Pasture degradation, %	10	94	0	46
Fertilisers N, kg $farm^{-1}yr^{-1}$	31	15	390	160
Supplements, kg $cow^{-1}d^{-1}$	2.0	1.6	0.8	1.6
Milk, kg $cow^{-1}d^{-1}$	7.4	6.4	8.6	7.6
Milk, t ha^{-1} yr^{-1}	3.43	2.41	4.71	4.38
Net income, \$ $ha^{-1}yr^{-1}$	1044	440	1472	939

Source: Holmann *et al* (1995)

vegetables and potatoes, while diversification into fruits and flowers for exports has been developing rapidly in recent years. Intensification has led to combining grazing and stall-feeding of planted forage (e.g. Napier and King grass), supplemented with molasses, other sugar crop by-products, green bananas, plantain pseudo-stems and brewer's grains. These locally available by-products are gradually replacing more expensive commercial feeds. Pure Holstein-Friesian cattle predominate, producing an average of 16 kg of milk d^{-1} (range: 5-27 kg) and fed concentrates at rates of 1 to 10 kg d^{-1}. Liquid milk and cheese are the main marketed products: cheese making has increased particularly in more distant regions of the highlands of Ecuador and Colombia (de Jong, 1996).

These intensive highland systems, which extend into the Andean eco-region, take advantage of the favourable agro-ecology for milk production (Quiroz *et al.*, 1997). As elsewhere in the tropics, these smallholdings demonstrate the high productivity possible in crop-dairy systems that exploit the important complementarities between crops and livestock consistent with the risk-aversive strategies of resource-poor households world-wide. The pasture-based dual-purpose systems of Latin America are another strategy by which risks are reduced, and these diversified systems contrast with the specialised, generally large-scale, intensive dairy farms found in the region.

1.6 CONCLUSIONS

Milk production in the tropics has some continent-specific characteristics: in sub-Saharan Africa, three quarters of the milk is produced by cattle, with common property natural pastures providing most of the feed; by contrast in Asia, where cattle produce half of the milk, and most of the remainder comes from buffaloes, crop residues are the major feed source; whereas in Latin America, most milk comes from cows grazing privately-owned planted pastures. Over-riding these characteristics of production systems are the effects of the market; throughout the tropics, with the exception of India and parts of Latin America, market-oriented smallholder (and large

scale) dairy farms are concentrated near or within–urban consumption centres. Less proximate production occurs only in those regions where there is an efficient market infrastructure. Therefore, the potential to increase dairy production depends largely on the unit costs of collection and transport. Those in urban periferies are doubly advantaged, because with better access to markets, the unit costs of the support services (input supply; animal health services; milk marketing) decrease as production increases (Walshe *et al.*, 1991)

The advantages of integrating dairy production into crop systems, however, also offer potential. Compared to pastoralists and agro-pastoralists, crop-livestock farmers have more control over feed inputs, and are able to capture complementarities in feed resource use and nutrient cycling, which increase overall farm efficiency and reduce vulnerability to market shifts. As these crop-livestock systems generally support high rural population densities, intensification is characterised by declining farm sizes, the upgrading to dairy breeds (whether cattle or buffalo) and an increasing reliance on purchased fodders and concentrates. As a result, lactation yields have increased up to five-fold (de Jong, 1996).

In these smallholder dairy production systems, especially those close to urban centres, informal raw milk marketing is often the general rule. Such markets are particularly susceptible to distance. As infrastructure develops, markets become more efficient and urban consumers develop stronger preferences for pasteurised milk, the advantages of proximity will be reduced and production may well move away from intensive peri-urban systems and shift to more extensive systems (as the New Zealand dairy industry illustrates on a global scale). Until these infra-structural improvements occur, and because of the advantages of mixed crop-livestock production, the industrialised model of dairy production and processing is likely to remain a minor contributor to dairying in the tropics.

In the meantime, dairy production will contribute significantly to the sustainable intensification of smallholder agriculture in the tropics, thereby enhancing the welfare of millions of poor households, whether through their participation in milk production, processing or marketing. These benefits of dairy production are especially important to the land-less poor, who, during the next 20 years, will increase significantly not only in Asia, but throughout the tropics.

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