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CLASSIFICATION OF MILK PRODUCTION SYSTEMS IN TROPICAL SOUTH AMERICA: A FIRST APPROXIMATION

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This paper is a first approximation of a classification of South American milk production systems, according to the degree of climatic stress and the type of forage utilization involved. The first criterion used is altitude, and the second is the feeding system of the cattle.
In the highland regions, the systems considered are based on grazing, chiefly of mixed grass-legume swards as in temperate zones, or intensive systems with cattle confined and fed on concentrates located near the large centres of consumption. In the lowland region, consideration is given to extensive, semi-intensive and intensive systems, according to the methods used to overcome the problem of seasonal forage shortages. Details of the different production systems are presented from case studies carried out on individual farms in Brazil, Paraguay, Bolivia and Colombia. The concepts described are incorporated into a model of milk production development in a hypothetical South American country, which has highland areas already in use and underpopulated lowland regions. The analysis presented emphasizes the importance of price as a mechanism which determines the relative importance of different milk production systems.

Key words: Milk production systems, South America, case studies, development model.

Compared with other parts of the world, South America is only of secondary importance as a milk producing zone, with approximately 10% of the world's milked cows and 6% of its total annual milk production(FAO,1980a). As shown in Table 1, the tropical part of the region is a net importer of milk products, but a considerable volume of milk is produced, based on low yields of large numbers of cows in milk (Table 2). However, a more detailed analysis shows that the range of different milk production systems which exists is very wide, reflecting the various physical, biological and economic conditions under which they have evolved.

Classification of production systems:

The breeds of cattle of highest milk production potential are derived from European (*Bos taurus*) breeds in temperate climates. Tropical conditions, especially high temperatures combined with high relative humidity, constitute a considerable stress for such animals (Bonsma, 1973). On the basis of this criterion, two large ecological zones with important cattle populations may be defined.

Table 1:

South America: net annual importation of milk products, according to country, 1979 (FAO, 1980a).

Country	Net importation[1] (metric tons)				
	Milk			Butter	Cheese and curds
	Powder and cream	Condensed and evaporated	Fresh		
Tropical region:					
Bolivia	6500	3000	-	-	-
Brazil	10236	50	-	699	895
Colombia	20250	130	-	5500	-7000
Ecuador	6891	-	-	-	-
Guayana	2000	10000	-	220	1200
Paraguay	230	-	-	-	-
Peru	12300	48	-	13000	800
Surinam	500	500	-	250	550
Venezuela	64325	2078	4060	216	6351
Temperate region					
Argentina	18300	-300	-	3500	-400
Chile	25982	361	-	9377	600
Uruguay	1100	-	-	-	-1100
South America Total:	168614	15867	4060	32762	1896

[1] Net importation = imports - exports.

Table 2:

South America: structure of milk production, according to country, 1979 (FAO, 1980b).

Country	Cows in milk (thousands)	Yield (kg/cow/year)	Production (metric tons 10^3 per year
Tropical Region:			
Bolivia	45	1233	55
Brazil	13150	806	10600
Colombia	2550	1059	2700
Ecuador	600	1433	860
Guayana	18	766	13
Paraguay	79	1899	150
Peru	733	1173	860
Surinam	14	601	9
Venezuela	1047	1207	1264
Temperate Region:			
Argentina	2700	1933	5220
Uruguay	480	1500	720
Chile	732	1270	930
South America:	22149	1056	23382
World:	214589	1955	419464

a) Highland regions (exceeding 2000 m above sea level).

Ecological conditions in these zones usually permit the use of European type cattle, principally the Brown Swiss and Holstein Friesian, kept on grazing. Pastures consist of temperate zone species such as ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), kikuyu (*Pennisetum clandestinum*) and forage legumes such as white and red glover (*Trifolium repens* and *T pratense*) or alfalfa (*Medicago sativa*). Production is usually continuous throughout the year, since there is no marked seasonal variation in pasture yields and the milk is destined mainly to meet the demand for the fresh product. Such systems are found throughout the Andean region. The most important example, on account of its scale, is the plateau round Bogota, but they are also found in the highlands of Peru and Ecuador and in the Andean region of Venezuela (Flores, 1974; Peña, 1981). Similar systems are also in use in Central America (Ruthenberg, 1980) and in Mexico (Sánchez et al., 1981).

When plant growth conditions limit pasture yields or where land prices are very high, highly intensive systems based on the use of concentrate foods tend to develop. Such is the case in the highlands of Ecuador where grazing is heavily supplemented or, as an extreme example, round Mexico City, where the cattle are completely confined and fed on alfalfa, chopped corn forage and concentrates.

To illustrate the high potential of highland grazing systems, a case study taken from the plateau round Bogota is presented in Table 3. The farm produces 6000 kg of milk/ha/year from rotationally grazed pastures, with fertilization after each grazing and overhead irrigation, but without the use of concentrates.

b) Lowland tropics (between 0 and 2000 m above sea level).

It is proposed to classify lowland systems, according to the intensity of land use and livestock, into extensive, semi-intensive and intensive.

i) Extensive systems.

These are based on the use of local criollo or zebu cattle, or their crosses, maintained exclusively on grazing. The balance between the supply and demand for forage is achieved in what Andreae (1972) described as a "passive" manner, that is to say, adapting the requirements of the herd to the supply by management measures such as determining the mating and weaning seasons, the season for selling culled stock, and permitting the loss of weight in certain classes of animals during the dry season, etc. As an example of such a system, a case study of a farm at San Javier in the Bolivian Chaco is presented in Table 3 (second column), using data given by Wilkins (1978).

The farm is situated in a semi-arid region with a total of 800 mm of rain per year, distributed in a single rainy season, where extensive beef production is the predominant form of land use. CORDECRUZ (Development Corporation of Santa Cruz) has set up a cheese factory and, as a result, a change towards extensive dual-purpose systems has occurred.

The system is based on permanent grazing of yaragua (*Hyparrhenia rufa*) and black grass (*Paspalum plicatulum*) without supplementation. Milk production is low: 334 kg/cow/year and 250 kg/ha/year. Cows go dry in the summer so that production is markedly seasonal. Purchased inputs are

Table 3:

Milk production systems in the South American tropics: technical and economic characteristics.

	Colombia[1]	Bolivia[2]	Paraguay[3]	Brazil[4]	Bolivia[1]
General information					
Region	Bogota	San Javier	Filadelfia (West Chaco)	Valle de Paraiba	Santa Cruz de la Sierra
Annual rainfall (mm)	1060	800	600	1300	900
Altitude (m above sea level)	2600	300	150	600	650
Annual mean temperature (°C)	15°	24°	25°	20°	25°
Year of data collection	(1977)	(1978)	(1976)	(1978)	(1979)
Production system	Specialized dairying	Extensive dual purpose	Dual purpose with agriculture	Semi-intensive dairying	Intensive dairying
Forage base	Temperate zone species irrigated	Native species	Introduced grass species, forage crops	Native and introduced grass species, forage crops	Introduced species, forage crops, silage
Kind of study	Case study	Case study	Model	Case study	Case study
Size of farm					
Area in crops/livestock (ha)	55	200	215	232	340
Area in grazing (ha)	55	200	40	226	312
Dairy cattle (animal units)	181	233	25	167	305.2
Man equivalent ME(Family ME)	9(0)	7(1)	1.5(1.5)	15(1)	8(0)
Land use (ha)	Kikuyu (26) Introduced species(29) (*D. glomerata, L. multiflorum, T. repens*)	Native species (200) (*H. rufa, P. dilatatum*)	Native species (11) Introduced species (29) Crops: Cotton (3.0) Peanuts (3.1) *Ricinus communis* L. (1.8) Subsistence crops (2.3) Bushland (164.8)	Native species (127) (*M. minutiflora*) Introduced species: *B. decumbens* (80) *P. purpureum* (8) *S. officinarum* (3) Forage crops: Corn for silage(8)	Introduced species: *B. decumbens* (163) Forage crops: Corn + *D. lablab* (17) Sorghum (14) Corn (32) *P. purpureum* (86)
Livestock inventory (head)					
Dairy cows	100	150	15	94	256
Dairy cow replacements	108	163	21	113	120
Beef cattle	0	83	7	3	16
Sheep and goats	0	0	0	0	0
Efficiency indices					
Milk yield/cow (kg)	3558	334	536	1527	824
Milk yield/ha pasture (kg)	6470	250	201	652	676
Beef production(kg live weight /ha)	257	117	64	n.d.	118
Beef production/cow (kg live weight/ha)	141	155	171	n.d.	144
Calving percentage (%)	80	50	85	n.d.	80
Stocking rate (A.U./ha pasture)	3.3	1.2	0.63	0.76	0.98
Labour (man hours/cow)	192	112	n.d.	351	75
Use of concentrates (kg/cow)	-	-	-	n.d.	210
Crop yields (kg/ha)	-	-	Cotton 670 Peanuts 760 *Ricinis communis* L. 620		
Prices (US $)					
Milk (litre, 4% fat)	0.20	0.15	0.12	0.28	0.21
Dairy cow	641	150	71.4	n.d.	900
Concentrates (kg)	-	-	-	n.d.	0.16
Annual wage	1261	1120	833	n.d.	1820
Land (ha)	8000	n.d.[5]	8	1628	500

Sources: 1) Seré (1981); 2) Wilkins (1978); 3) Pascale et al. (1977); 4) CATI (1979) and Moraes Biral, M. A. (Personal communication).

5) Not available

limited to a minimum of veterinary products and mineral salts. The sale of cattle generates an important part (47%) of the gross product of the farm, which indicates the importance of beef production as a means of making use of the highly seasonal supply of forage.

ii) Semi-intensive systems.

The gradual intensification of the extensive systems is indicated by the use of pure or crossbred bulls of European dairy breeds. Furthermore, to a greater or lesser extent, "active" measures (Andreae, 1972) are taken to adjust the supply of nutrients in the diet, such as supplementation with chopped sugar cane, elephant grass, silage, concentrates, etc., during the dry period of the year.

In the Chaco of Paraguay, a region similar to the Bolivian Chaco mentioned above, Mennonite immigrants have developed a mixed farming system with crops and dual purpose cattle. The reasons for the evolution of this kind of system are to be found partly in the size of the holdings (various hundreds of hectares) and partly in the mixed farming traditions of these temperate zone immigrants. Water is the chief limiting factor. Annual rainfall amounts to approximately 600 mm, occurring in a single rainy season. Since subterranean water is also scarce, rainfall is conserved with dikes. Buffel grass (*Cenchrus ciliaris*) is the principal introduced pasture species, due to its high tolerance of drought conditions.

Low stocking rates are used (0.63 A.U./ha) and silage is made for the dry season. Almost no concentrate food is employed. The criollo-zebu livestock are being crossed with Holstein Friesians and cows milked once daily with calf at foot. All male calves are sold as steers. Milk is collected by cooperatives which make cheese and both milk and cheese are sold in the Asuncion market, 450 km away. Despite relatively low producer prices and the fact that the region is marginal, these producers obtain an aggregate value of US$0.55 per man hour employed. This is achieved partly because the standard of management is greatly superior to the average, and partly because a high proportion of the jobs such as ploughing and harvesting cotton are carried out by contractors. This reduces the capital investment and the labour requirements. The high degree of cooperation between the producers is probably due to their religion and common cultural background.

The Paraiba valley in Brazil has developed as an important dairying zone supplying Sao Paulo, with its 12 million inhabitants. The system is more intensive than that described in the Chaco of Paraguay due, among other factors, to more favourable ecological conditions (annual rainfall of 1300 mm and mean temperature of 20°C) and to the close proximity of the market.

The dairy farms are usually located in steep, hilly areas with eroded, acid soils which have few possible alternative uses. The farm described in Table 3 belongs to the group of large producers of grade B milk, which has certain quality prerequisites but no official price control until after 1978 when the study was made. Forage is based on natural *Mellinis minutiflora* and introduced *Brachiaria decumbens* grazing species, elephant grass (*Pennisetum purpureum*) and sugar cane (*Saccharum officinarum*) for cutting, and corn silage. Concentrates based on wheat

and maize bran, oats and cotton seed cake are also used. The cattle are 3/4 - 7/8 Holstein and 1/4 - 1/8 Zebu and are milked twice daily with the calves at foot. Male calves are reared up to two years of age.

Concentrate use is heavy but milk production levels are relatively low (1527 kg/cow/year, 652 kg/ha/year). Despite the large size of the farm, there is a high labour input per cow because of the use of hand milking and of cut and ensiled forage.

iii) Intensive systems

The low output, in terms of milk and meat per cow and per ha, of the extensive tropical production systems has led to a series of attempts to transfer to the lowlands, systems similar to those employed in the temperate highlands. This tendency has been encouraged in many cases by the existence of large volumes of agroindustrial by-products such as soya meal, cotton seed cake, molasses, sugar cane tops, etc, which are potentially valuable dairy cattle feeds. In addition, the official policy of many countries has been to introduce pure European dairy cattle in order to obtain a rapid increase in production from a "modern" dairy sector, supposedly more efficient than the traditional extensive systems. Nevertheless, few producers in the lowland tropics have adopted such production systems, although a number of public agencies and international assistance institutions are involved in intensive dairying projects. It should be pointed out that intensive systems with animals in permanent confinement, such as those described by Preston (1976) and Donefer (1981) may be a viable option under conditions such as those prevailing in most of the Caribbean where land is very scarce, labour is abundant and there exist agroindustrial by-products such as those derived from sugar cane with a very low opportunity cost.

The intensive farm in Santa Cruz de la Sierra, Bolivia, details of which are given in Table 3, runs a purebred Holstein herd brought in from Cochabamba and Argentina. Cattle graze pangola (*Digitaria decumbens*) for some hours each day and are kept confined the rest of the time, consuming chopped elephant grass, corn - *Dolichos lablab* mixture of sorghum. The herd is kept in at night because of the poor condition of the fences. The soils are poor and sandy and when the information was collected, the farm had just experienced an acute shortage of forage due to drought and overgrazing. As a result, many replacement heifers were sold and cows dried off.

The system was planned to operate with low levels of concentrate feeding. Due to the problems experienced with forage production on the farm, milk production levels have fallen considerably. The higher yielding cows are milked twice daily and the rest once only. Calves are bucket reared at pasture.

The economic efficiency of the farm is surprisingly high in spite of the low technical efficiency, a fact which is explained by the high prices paid in Santa Cruz for Holstein heifers and calves. The culled stock are sold for double the price of culled beef cattle.

The structure of the demand for milk products, and its implications.

The fact that a high proportion of the total milk consumed in South America is in the form of cheese has had an important effect on the

Table 4:

Milk production systems in the South American tropics-Availability of resources, use of inputs and productivity.

	Colombia[1]	Bolivia[2]	Paraguay[3]	Brazil[4]	Bolivia[1]
Capital (US $)					
Land	470000	n.d.	1707	464234	170000
Buildings and fences	12050	n.d.	7694	27130	44860
Livestock	117380	n.d.	2952	46120	275950
Machinery	26640	n.d.	397	10852	23500
Total	626070	n.d.	12750	510336	514310
Gross income (US $)					
Milk	68200	8750	957	41349	33869
Beef	18645	7800	715	6794	73728
Crops	0	0	1556	0	0
Other	0	0	0	0	0
Total	86845	16550	2228	48143	107597
Purchased inputs (US $)					
Seed	550	0	61	(a)	3400
Fertilizer	10505	0	-	(a)	3870
Concentrates and minerals	1375	50	17	11058	7726
Other livestock expenses	1595	200	39	678	4000
Machinery	5445	0	127	(a)	8820
Other	605	3775	1017	11528(b)	2650
Total	20075	4025	1261	23264	30466
Aggregated value (c)	66770	12525	1967	24879	77466
Salary non-family labour	22110	6720	-	10158	13200
Family income (d)	-	-	1967	14721	-
Net income (e)	44660	5805	-	-	69931
Labour productivity					
Net income/man equivalent/year	9649	2364	2152	3210	13450
Aggregated value/man equivalent/year	7418	1789	1311	1659	9641
Labour use (man hours/year)	21600	16800	3600	33000	19200
Aggregated value man hour	3.09	0.75	0.55	0.75	4.02

(a) Since these costs were not differentiated according to separate items, all are included in "other".
(b) Includes 5% depreciation on buildings and machinery inventory.
(c) Aggregated value gross income less material inputs.
(d) Return to family labour, administration and total capital.
(e) Return to total capital.

Sources: 1) Serê (1981); 2) Wilkins (1978); 3) Pascale et al. (1977); 4) CATI (1979) and Moraes Biral, M. A. (personal communication).

spatial distribution of the milk producing systems. By making cheese, the perishable product, milk, is transformed into one which is easily stored and whose high value justifies higher transport costs. This is the case in the examples described from the Brazil, Paraguayan and Bolivian Chaco. Huge areas, like the "cerrado" of Brazil market milk in the form of cheese. In the temperate zones of South America, the production of cream has a similar function, but not in the lowland tropics because of the difficulties of storage. Another factor which tends to favour milk processing is that it is frequently policy to control the price of fresh milk but not of milk products.

In Africa and Asia, the situation is completely different because there is less consumer preference for cheese. Milk production is concentrated round the large markets and in densely populated rural areas where milk is sold fresh to other rural consumers, as is the case in the highlands of Kenya (Stotz 1979).

The South American tropics offer a large amount of poor quality forage, suitable for extensive livestock production at a low marginal cost. Dairy production, on the other hand, requires a supply of better quality forage more evenly distributed throughout the year. This can only be obtained at higher marginal costs per forage unit. Under such conditions, beef is a cheap source of protein, while milk and cheese are considered more as luxury items, a fact which is reflected in the income elasticity of 0.5 to 1.0 reported for milk products in a number of Latin American cities (Rubinstein and Nores 1979).

The potential for expansion of milk production in highland regions.

As has been shown above, efficient systems in terms of output of milk per cow and per year are to be found in the highlands, mostly based on technology developed in temperate parts of the world. In theory, milk production could be increased by incorporating new areas of land or intensifying the use of the land already in dairying. The opportunity cost of land in most highland regions is high because of the high density of population and due to the existence of alternative forms of land use, thus limiting the possibility of expansion of the area dedicated to milk production. The possibility of intensifying production on the land already in use does exist, but important technological innovations which might permit this are not available and increases in yield will be obtained by gradual changes in existing production functions, with increasing marginal costs, principally by means of higher levels of pasture fertilization.

The potential for expansion of milk production in the lowland tropics.

The traditional system of milk production in this region is a dual purpose one. As shown by Von Oven (1969), the dual purpose system leads to an important increase in returns per cow, as compared with extensive beef production. Whether or not it is competitive depends on the relative availability of land and labour and access to markets for milk or cheese.

Dual purpose enterprises contribute an important proportion of the total milk produced in these regions. Valdes and Nores (1978) cite studies to show, for example, that in Nicaragua 70 to 80% of lactating cows are milked, while in Colombia over 50% of the milk consumed comes from dual purpose systems. In Brazil, the corresponding figure is about 35%.

The dual purpose system of production is very well suited to the region. Cows are milked once daily in the rainy season when higher forage quality and, consequently, improved intake, leads to an excess of nutrients above those required for maintanance, which may be transformed into milk. The expansion of this system by incorporating into it additional land areas depends on the improvement of road communications and milk marketing facilities.

The intensification of milk production using resources which are already in use becomes attractive when there is an increase in the price of milk relative to that of the inputs involved, and as transport costs increase due to increasing distances to markets or rises in the cost per kilometre.

The intensification of this kind of system requires a simultaneous change in the forage used and in the type livestock which makes use of it. Such a change has the following consequences:

- An important increase in production per cow and per ha.
- Crossbred European cattle require better quality pasture and more even distribution of forage supply throughout the year. In most cases, this requires the use of introduced grazing species and/or pasture conservation or concentrate feeding.
- The greater intensity of these systems, compared with extensive ones, implies a change with regard to health conditions. The higher incidence of internal parasites, ticks and blood parasites makes higher demands on farm administration capacity.
- Intensive systems require two milkings per day. Lack of rural electricity supplies and, thus, of efficient means to keep the milk cool often make it difficult to put this measure into practice.
- The high capital investment needed for housing and the costs of skilled labour imply important increases in overall costs. The fixed costs per cow diminish as the number of cows maintained falls, thus giving an advantage to large herds. Systems based on permanent confinement on small farms, such as those in Kenya described by Stotz (1979) have an extremely low efficiency in terms of returns per man hour employed, and for this reason usually cannot compete with alternative uses of labour. However, it should again be made clear, that the situation may be different as, for example, under present conditions in parts of the Caribbean.

The results obtained by Wilkins et al (1979) in Santa Cruz and by others, suggest that under lowland tropical conditions, semi-intensive systems using crossbred cattle offer the best possibilities for increasing milk production, while intensification to higher levels using stabled European-breed cattle should be regarded as a big "jump" to another production function which must require a substantial increase in the price of milk in order to be economical.

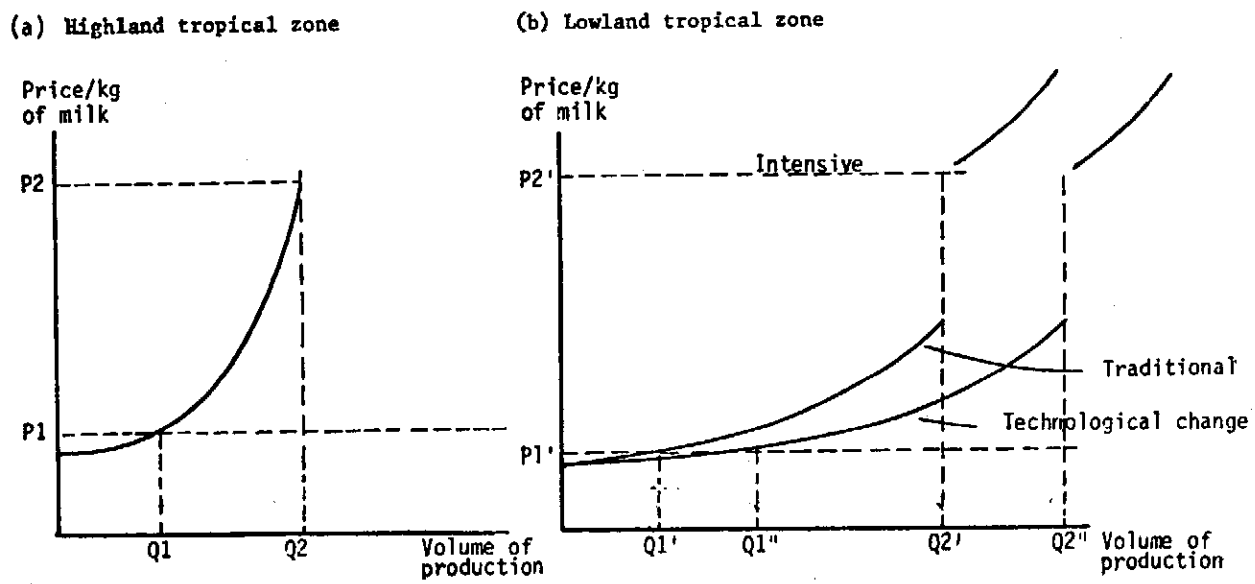
Technical model for the process of expansion of milk production

Figure 1 illustrates a model which takes into account the possibilities for expansion discussed above for a hypothetical South American country with a limited and densely populated highland area and a vast, under-populated lowland region. The highland regions produce along a uniformly continuous function with region. The highland regions produce along a uniformly continuous function with rising marginal costs. The slope is relatively high at levels of production superior to those actually obtained due to the high opportunity cost of the land and to the use of fertilizers with decreasing marginal yeilds. The low price of milk compared with that of concentrates means that the generalised use of the latter would only be economical at much higher milk prices than those presently obtained.

Lowland tropical regions present a different production function. With small rises in prices, huge additional land areas could be incorporated into milk production and the systems gradually intensified to semi-intensive levels.

Increases in the demand for milk and milk products, caused by population increase or higher per capita incomes, result in higher milk prices. In the present model these are manifested by a higher proportion of the total production in the lowland regions. Once the potential of semi-extensive systems is fully exploited, major price increases are required to expand production from intensive systems in lowlands.

Figure 1:
Regional functions of milk supply.



P1 y P1' : Actual prices in high and lowland tropical zones, respectively.
P2 y P2' : Prices necessary to justify intensive systems in lowland tropical zones.
Q1 y Q1' : Actual production levels in both zones.
Q2 y Q2' : Production levels at prices P2 and P2'.
Q2" y Q2' : Rise in production in lowland tropics due to technological change in dual-purpose systems.

Faced with the prospect of increasing milk prices, two possibilities exist to reduce the trend: open the market to the very elastic supply of the international trade or introduce technological changes. An extremely promising possibility would seem to be the improvement of pastures using grass-legume associations, thus gradually allowing the intensification of dual purpose systems. Both producers and consumers would benefit from a policy of this nature and though the benefits would be obtained partly at the expense of highland producers, the latter would have a series of possible alternative uses for their production resources.

Conclusions

Milk production from dual purpose systems could be substantially increased, by means of price increases and/or technological change.

Transport costs are a variable which greatly affect the economic success of dual purpose systems. Research should be encouraged on ways to preserve milk other than by cooling and on improved technology for cheese making on the farm or in small local industries.

In social terms, other things being equal, it is better to subsidise the improvement of pastures, transport and marketing than to import purebred dairy breeds or to use concentrate feeds.

The cross-price elasticity of supply of milk and beef should be studied in order to determine appropriate policies. This means an analysis of the reaction of producers in terms of change in the supply of meat as a result of changes in the price of milk, and vice versa. Information regarding such producers reactions is essential in the design of livestock production policies in the tropics.

As the opportunity cost of foreign exchange increases, the benefits of developing dual purpose systems become more marked. This is due to the direct effect of substituting milk imports and to the indirect effect of replacing intensive systems which are usually based on concentrate feeds derived from imported cereals.

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