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Title: **RUMINANT PRODUCTION SYSTEMS IN DEVELOPING COUNTRIES: RESOURCE UTILISATION**

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Abstract

Ruminant production systems are discussed with specific reference to effective use of the resources that support them. Particular emphasis is given to the main production and under-utilised resources: animals and feeds. The ruminant animals include buffaloes, cattle, goats, sheep and camels, which with the exception of sheep, account for between 94-100% of total world population in the developing countries. Their biological attributes, including inherent characteristics, feeding behaviour and metabolism are summarised. The feed resources include extent and availability of permanent pastures, crop residues, agro-industrial by-products and non-conventional feeds. The prevailing ruminant production systems are classified into three main categories: extensive systems, systems combining arable cropping (roadside, communal and arable grazing systems; tethering and cut-and-carry feeding), and systems integrated with tree cropping. Their genesis and endurance with patterns of crop production and farming systems are addressed. Integrated systems involving animals and tree crops are potentially important. Existing ruminant production systems are unlikely to change in the foreseeable future, unless there are major shifts in resource use and the proposed new systems are demonstrably superior. Factors likely to influence the future of these systems are market requirements, available feed resources and growth in human populations. Increased priority to buffaloes, goats, sheep and camels is appropriate, consistent with their potential contribution to meat, milk, fibre and draught power. The principal strategy to sustain this productivity is more complete utilisation of the available feed ingredients and possible increases. The latter needs to be supported by the development of innovative year round feeding systems which can clearly identify the objectives of production with socio-economic benefits. These measures together, should provide for increased efficiency in the use of the production resources, and sustainable ruminant production systems in the developing countries.

1. INTRODUCTION

The efficient utilisation of production resources represents a principal determinant of the economic importance of ruminant production systems. The magnitude of this success is largely influenced by the manner in which the production resources are utilised, and in particular, improved methods of their utilisation within the systems. An overriding influence on the production systems and the utilisation of resources to support them is that of the agro-climatic environment, since adaptation, ability to thrive in different situations, and extent of expression of the genetic potential of animals are dependent on the interaction of the climatic components, mainly temperature, radiation, humidity and rainfall [1].

The agro-climatic environments in the developing countries, and in particular, the arid, semi-arid and wet tropics are unique in that the regions present contrasting extremes of the effects of climatic components, and therefore differential responses in animals. These bioclimates range from tropical desert characterised by temperature extremes (0° to 52°C), insignificant rainfall and sparse vegetation, to the wet tropics with high temperature, humidity and rainfall (3000 to 5500 mm), and abundant vegetative cover. In both situations, ruminants play an important role in agriculture and render valuable service to man. These range from bedouins with their camels, goats and sheep practicing shifting agriculture in the arid regions of northern Africa, to small farmers with water buffaloes (Bubalus bubalis) and cattle in complex crop-livestock systems in monsoonal Asia. In this region, meat, milk and draught are vital contributions by these species.

In a farming system context, the agro-ecological conditions are the main determinants of crop and livestock systems that develop in any one situation. Ruminant production systems are particularly dependent on vegetation, arable and perennial cropping for their feed base. The feed component is especially relevant as it is the primary link between crops and animals, the interaction and understanding of which, also provides for important socio-economic factors advantageous to farm households and landless peasants, and the stability of farming systems.

The intent in this paper is to examine and enquire into the nature of the production resources, mainly animals and feeds available in the developing countries, and the extent and efficiency with which these are currently being utilised to support ruminant production systems. More particularly, the paper addresses the opportunities for further improving prevailing patterns of production, possibilities for increasing productivity from animals, and need for more emphasis on the more important production systems.

2. THE PRODUCTION RESOURCES

2.1. Animal resources

Table I compiled from FAO statistics [2,3,4], presents the type and magnitude of the animal resources in the developing countries. Between 94-100% of the total world population of buffaloes, camels, asses and goats, 67% of the cattle and 53% of sheep are found in these parts. Thus all the meat and milk from buffaloes, and about 93% and 55% of the total world output of goat meat and milk are produced in the developing countries.

Unfortunately, limited statistics are available on the contribution of herbivores to draught animal power. Buffaloes, cattle, asses, camels and horses and mules are widely used throughout the developing countries for draught power, ranging from a wide variety of ploughing operations to transportation, but little is known about this contribution and the effects on crop production, and possibilities of how potential increases in draught power will affect farming systems. FAO [5] in its study of agricultural projections, has calculated that the power inputs in developing countries would have to increase by 2.3% per annum to achieve an overall agricultural growth rate of 3.4% per annum until the year 2000. This would involve an overall increase of 15% in the number of draught animals, but an increase of 400% in tractor numbers. The latter involves considerable capital expenditure and which may not be easily available, in which case, the importance of draught animals and their contribution to a variety of uses in agriculture and farming systems are likely to assume much greater importance in the future.

Among ruminants, the annual growth rate over the period 1975-1985 indicated that the goat and sheep populations grew the fastest, followed by cattle. The buffalo population was static, and among the herbivores, the animal growth rates in camels and mules were the highest. Among non-ruminants, the chicken population grew at a very rapid rate, followed by the pig and duck populations. It is interesting that among the herbivores, the neglected species (goats, camels and mules) had the highest annual growth rates.

Between ruminants and non-ruminants, development programmes have generally tended to concentrate mainly on cattle for milk production for several reasons: of daily milk production, means of collecting daily cash revenue, readily available production technology from industrialised countries, the value of dairying as an important means to promote social and economic change, as well as the pace of rural development.

2.2. Biological attributes

It is appropriate to briefly discuss the more important attributes of the animal resources and characteristics of their feeding behaviour and metabolism. Table II summarises the more important features of individual features in arid and wet zones.

Water buffaloes in the humid tropics are particularly well adapted to take advantage of the high rainfall and high humidity. The skin thickness is about two to three times greater than that of cattle, is indented, heavily pigmented and provides protection from radiation. An adaptational factor in water buffaloes is the relatively small number of sweat glands (140-150/cm^2 vs 800-1500 /cm^2 in cattle). These glands show a tendency to atrophy which further limits the water buffaloes' capacity to loose heat; it is not clear when the glands atrophy but this characteristic contributes to their relatively low heat tolerance compared with cattle. When exposed to direct sunlight, water buffaloes significantly increase their rectal temperature, respiratory rate and heart rate [6,7,8]. Nevertheless, water buffaloes are capable of activity in open sunlight and in situations where there are no wallows [9]. In these situations, they attempt to dig holes to remain cool. Their capacity to work in open sunlight is probably related to a decline in metabolic heat production during prolonged exposure to heat [10].

Zebu cattle (Bos indicus) in Bangladesh fed with untreated rice straw have been reported to have significantly greater rumen and total gut contents than those given urea-treated rice straw. Expressed as a percentage of live weight, both groups and gut contents and tissues are far greater than European cattle (Bos taurus) [11]. This could be genetic or due to adaptation, but is an advantage to these animals in utilising coarse roughages.

In the semi-arid and arid regions, relatively taller animals are apparent, with loose skins and appendages. The larger size is an advantage in these environments because of smaller relative surface area, and this advantage is maximal where there is much exposure to direct radiant heat. Goats and camels are particularly adapted to this environment which is characterised by very high temperatures, very low rainfall and sandy soils. The situation is well illustrated by larger (30-50 kg live weight) and taller (70-100 cm height at withers) goats found here, compared to smaller (910-25 kg live weight) and shorter (50-65 cm height at withers) goats found in the humid regions.

Goats in arid regions absorb low amounts of solar radiation, can withstand dehydration and show greater capacity for survival in this environment than do sheep. In the humid tropics, dwarf goats of the Fouta Djallon type are common in West Africa. The precise reason for dwarfism is not known, but it has been suggested that this is an adaptation to poor nutrition and a low metabolic rate [12].

The fat tail of some sheep breeds such as the Awassi in Israel, and the Barki, Ossimi and Rahmani in Egypt is an important adaptive mechanism of significance in enabling grazing for long distances in the dry season. The storage of fat in the tail provides an important source of energy during periods of feed scarcity such as droughts. Fat tail breeds thus assume greater significance in arid and semi-arid regions.

Camels in the arid regions are distinctively one-humped, which together with the long neck and legs enable adaptation to a very harsh environment. In addition, the camel has long eye lashes and nostrils that are almost closed to protect it against the sand in the desert.

2.3. Feeding behaviour and metabolism

Table III presents a summary of the main differences in the feeding behaviour and metabolism of ruminants and equines. In the arid and semi-arid region, animals generally walk long distances in search of feed and water, much more than in the humid and subhumid region where they are more sedentary. The longest distances walked are by camels, with progressively lesser distances by goats, sheep and cattle. This pattern is also consistent with the fact that goats and camels are very much better adapted to heat stress, can withstand dehydration and survive on very low planes of nutrition, utilising desert shrubs and coarse roughages. Their browsing habits are facilitated by the possession of split upper lips and, in the case of camels, long necks.

Water buffaloes have certain metabolic features that are characteristic of the species. They have an ability to utilise low quality forages more efficiently, but evidence for an inherent species ability remains to be established [13]. Recent experiments in Australia [14,15,16] suggest that the advantages the swamp buffalo might have over cattle are associated with an increased recycling mechanism of urea from the blood to the rumen, higher rates of non-rumen ammonia nitrogen, longer rumination times and faster rate of passage due to the force of fore-stomach contractions.

Water buffaloes consistently exhibit a greater ability to utilise nitrogen than cattle. On low quality roughages, these animals have been found to have a higher plasma urea concentration and therefore a greater absorption of urea than zebu cattle [17]. Both the swamp buffalo [13,17] and the Murrah buffalo [18] have been shown to have higher nitrogen retention than do zebu cattle, resulting from a lower urinary nitrogen retention than to zebu cattle, and due to a lower urinary nitrogen output and efficient glomerular filtration [19,17]. Buffaloes have also been reported to have a higher concentration of bacterial nitrogen than zebu cattle [18,20,21] and total nitrogen content [22,23,24] of rumen contents. Dry matter degradabilities of different sources of protein fed together with untreated rice straw and urea-treated rice straw have been shown to give higher values for water buffaloes compared to cattle [25].

Cattle and sheep are essentially grazing animals and thrive on a variety of grasses, forages or agro-industrial by-products. Their digestive efficiency is comparable, and hence sheep are often used to evaluate the nutritive value of feeds. By comparison, goats and water buffaloes appear to have the ability to utilise coarse fibrous feeds more efficiently than do cattle or sheep. Precise reasons for this are not clear, but are associated with feed particle size, amount of salivary secretion, rumination, concentration of cellulose splitting micro-organisms, fermentation rate, absorptive capacity water turnover, recycling of urea, rate of passage and retention time [12]. Differences in saliva secretion between goats and sheep are evident when given the same feed, with production rates of 848 ml and 502 ml/day respectively [26]. Differences in saliva secretion are likely to influence urea recycling, an important factor in fibre digestion. There appears to be an important breed difference in urea recycling; Black Bedouin goats recycled 0.18 g N-urea/kg live weight which is twice that produced by Saanen goats fed the same diet [27].

By comparison, goats are browsers and have a bi-pedal stance [28]. They have a competitive advantage over sheep in woodland and shrubland, are generally more active, selective, walk longer distances in search of feed and relish variety in feeds [29]. Thus they are natural leaders of mixed goat and sheep flocks in many developing countries. Another feature of the feeding behaviour of goats is their discerning ability to taste. Goats can distinguish between bitter, sweet, salty and sour tastes, and show a higher tolerance for bitter taste than do sheep and cattle [30,31]. Additionally, some desert goats such as the Egyptian

Zaraiby are known to have lower resting metabolic rate than would be predicted from the known equations relating body weight, metabolic rate and surface area [32]. Such an adaptation is advantageous to life in the arid zones where water and feed are severe limiting constraints.

Recently, attention has been drawn to the higher rumen NH_3-N in goats which has been attributed to greater rumen protein degradation as a result of a longer retention time of digest in the rumen [35]. Since goats drink less water than sheep per unit dry matter intake [34,35,36,37], it has further been suggested that the lower water intake may be the cause of the higher rumen NH_3-N concentration [38].

2.4. Feed resources

The feed resources refer to the availability from permanent pastures, forest and woodland, crop residues, agro-industrial by-products and non-conventional feeds.

2.4.1. Permanent pastures, forest and woodland

Table IV sets out the extent of permanent pastures available and also land under forests and woodlands. Also given in the table is the corresponding magnitude of the ruminant livestock units available, based on calculations from FAO data. Of particular significance is the marked imbalance between the total ruminant livestock units and available permanent pastures in Asia compared to the other regions. It is in this region, to include centrally planned economies, more than any other, that there exist acute feed shortages to meet the requirements of ruminants, such that continuing low per animal performance is more the rule rather than the exception. The importance of making maximum use of all available feed resources thus assumes far greater importance, and a particularly important strategy in this situation.

The forests and woodlands have also been included in the table to provide a reminder about the potential importance of the herbage available under these perennial tree crops, including also the use of some of the more important leaves. These feed resources have not been adequately utilised in the past for want of adequate methodology to facilitate the process of integration, involving appropriate choice of species, objectives of production that can ensure high productivity from the land due to the combined thrust of both animal and crop association. In South, South East Asia and the Pacific Islands for example, there exists about 20 x 10^6 ha under tree crops, and even if only half of this crop area is utilised by animals, the number of animal equivalents that can be carried, and productivity from them, assumes considerable magnitude [39].

2.4.2. Crop residues, agro-industrial by-products and non-conventional goods

In addition to feeds from pasture, ruminants in the developing countries depend on three other categories: crop residues, agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR).

Crop residues are mainly fibrous materials that are by-products of crop cultivation. Due to the intensity of and emphasis on crop production in Asia, these form a high percentage of the total volume of the feeds produced annually.

Crop residues have a generally low crude protein content, in the range 3.3-13.3% on a dry matter basis. This suggests a basic limitation in the value of some of the resides (e.g. bagasse and rice straw) around the border line of the 6-7% dietary crude protein level required for promoting voluntary matter intake

(VFI). Most of the residues are deficient in fermentable energy, reflected by the relatively low organic matter digestibility, and also the availability of materials.

Agro-industrial by-products refer to the by-products derived in the industry due to processing of the main products. They are, in comparison to crop residues, less fibrous and more concentrated, and have a higher nutrient content. Good examples of AIBP are molasses, rice bran, pineapple waste, palm oil mill effluent (POME) produced from refining the palm oil and coconut cake. In this paper, and for reasons of brevity, AIBP is used in general to include crop residues.

Non-conventional feed resources (NCFR) are identified separately although they can be components of both crop residues and AIBP. NCFR refer to all those feeds that have not been traditionally used in animal feeding and/or are not normally used in commercially produced rations for livestock. Whereas the traditional feeds of crop origin tend to be mainly from annual crops, the NCFR include commonly, a variety of feeds from perennial crops and feeds of animals and industrial origin.

Examples of NCFR are oil palm by-products, single-cell proteins, feed materials of plant and animal origin (e.g. poultry excreta), and poor-quality cellulosic roughages from farm residues such as stubbles, haulms and vines.

Table V summarises the availability of NCFR in Asia and the Pacific. From field, plantation and tree crops alone, the total availability is approximately 513 million tonnes. Of this, about 238 x 10^6 tonnes or 46% are considered to be NCFR. This total availability is higher than the figure suggests, as it does not include calculations of feeds derived especially from animal slaughter and the food processing industries.

The importance and significance of using all available feeds are demonstrated in Table VI based on data on feed availability and requirements in India between 1970 and 1984. Two major conclusions are apparent. Firstly, feed deficits and the malady of under-nutrition was a continuing problem. Secondly, there has been a trend towards a reduced feed deficit despite an increased animal population over the 14 years. The trend towards reduced feed deficit is reflective of improved feeding systems, more efficient use in the available feeds, and increasingly intensive systems of production. Further improvements in this direction are likely, and Reddy [41] has pointed out that many more NCFR remain to be used to further reduce the feed deficits.

3. RUMINANT PRODUCTION SYSTEMS

Ruminant production systems have evolved in response to the agro-ecological environment, and also the availability of land, type and nature of cropping patterns (annual and perennial), the frequency and intensity of cropping, area of uncultivated land, species and animal numbers.

The genesis of livestock systems has its roots on prevailing climate, and to a lesser extent soils, which determine the suitability or otherwise of the types of crops to be grown. FAO [42] has provided a valuable illustration of the genesis of livestock systems. Of particular importance in Figure 1 is the feed base, its quality and dispersion, which together influence the type and intensity of ruminant production systems. The change from traditional to commercial systems is largely dictated by economic forces such as relative prices of feeds and animal products, commercialisation, growth in incomes and populations. The development of commercial systems are dependent mainly on inputs from overseas (animals and feeds) and therefore are less influenced by the agro-ecological environment. The capital investment in commercial systems is generally greater, production is more intensive and a good example is the beef feed lot.

3.1. Types of ruminant production systems

The prevailing ruminant production systems can be classified into three main categories as follows:-

1) Extensive Systems
2) Systems Combining Arable Cropping
   i) Roadside, communal and arable grazing systems
   ii) Tethering
   iii) Cut-and-carry feeding
3) Systems Integrated With Tree Cropping

3.1.1. Extensive Systems

This system is by far the most common for all types of ruminants. It is characterised by animals, usually owned by small farmers, landless peasants and nomads, grazing on all available grazing areas, largely uncultivated, including marginal land, for varying periods during the day. The length of the grazing period is dictated primarily by the type of ruminant and the objectives of production, mainly meat, milk, draught, fibre or combination of these.

The system has certain very definite features. Rearing ruminants is secondary to crop production, consistent with the pattern of agriculture. Usually, more animals tend to be carried than in the intensive system, probably because these animals have access to plenty of grazing land. Buffaloes and cattle tend to be grazed separately but where small ruminants are grazed together, goats and sheep are reared together probably because goats tend to lead the herd. Additionally, the small ruminants tend to be herded over longer distances compared to buffalo and cattle, which are relatively more sedentary.

The flock sizes of goats and sheep are larger (1-15 head), in small farm systems and those belonging to several owners, are usually run together and brought back in the evening. Stocking rates are usually in the range of 1-4 head/ha. Very extensive systems are rare, as with other parts of the humid tropics, presumably because of the availability of more forage and crop residues.

In the extensive system, a low level of unpaid family income represents the main input. By implication, the use of this unpaid family labour, usually women and children, represents an aspect of effective labour use whereby both cropping and rearing of ruminants represent important components of farm income. Except for the use of this low labour input, the system is principally one of low resource use, and a generally low level of productivity emerges from substandard nutritional management where very little or no concentrates, salt, or mineral licks are provided, except in the case of dairy cows.

A shift from extensive to systems combining arable cropping is influenced mainly by rainfall. Whereas in extensive systems ruminants are the sole enterprise, in mixed crop-animal systems, these animals play a complimentary role, the extent of which is dependent on size of the holdings, type and extent of crop grown and the contribution of animals.

Factors likely to influence the future of extensive systems include :

- o Legume introduction, establishment and management,
- o Fencing, and control of stock rates,
- o Enhanced genetic potential of animals,
- o Market development; including better health control.

3.1.2. Systems combining arable cropping

Ruminant production systems combining arable cropping have evolved in situations where crop production is important to contribute to the stability of the system. Animals do not compete for the same land and play a supplementary role to arable cropping. Three types of systems are common: roadside, communal, and stubble grazing; tethering; and cut and carry feeding.

The three systems are not mutually exclusive. Grazing on road sides and on communal (waste) land may be practiced by landless stock owners as well as others when their privately owned lands are under arable crop cultivation. Grazing in rice fields is restricted to periods immediately after harvest when the feeds available consist of the aftermath of the rice crop (i.e., rice stubble and some regrowth from the stubble), any weeds that grow in the paddies, the grasses that are found on paddy bunds, and browse and shrubs and trees that grow in it. Where multiple cropping is practiced, the crop aftermath may be burnt after the harvest and stubble grazing may be severely restricted or non-existent.

Tethering is adopted when there is a need to prevent animals wandering into areas being cropped and to ensure that they graze down the available feed in a given area before they are moved. This type of confinement feeding is most popular in South East Asia because multiple cropping is widespread in this region. The animals may be tethered on waste grazing areas close to the farm, or on rice fields after harvest to regulate stubble grazing or close to stacks or rice straw to allow self-feeding.

In the cut and carry system, a large proportion of the feed is usually brought in from outside the holding area because of the small size of land in relation to the number of animals kept. The system is subject to the vagaries of seasonal abundance and shortage of forage that characterise it. Because the livestock are housed most of the time, their dependence on high-priced concentrate feeds increases during lean periods. The system has had limited success because of the value of arable land for food production. This also presents a constraint to forage production for animals. The emphasis on crop production, however, makes large quantities of crop residues available, which are valuable as feeds, especially to ruminants.

The cut and carry or stall-feeding system requires high labour and capital investment. It is a system that favours situations where there is no land or, more particularly, the availability of abundant supplies of crop residues and agro-industrial by-products. Probably because of the higher capital investment, it has not been adequately used as a system. In Fiji, it has been reported that goats fed sugar cane tops, stovers, straws, coconut cake, rice bran, and molasses reached live weight of 23-25 kg in about 22 weeks with a daily live weight gain of 154 g, compared with 83 g in the extensive system [43]. Likewise in Thailand, Prucsasri <u>et</u> <u>al</u>. [44] have demonstrated that stall fed Brahman X Charolais X native crossbred steers given concentrates and fresh Guinea grass (Panicum maximum) had an average daily gain of 1.1 kg/head. When sold, the finisher cattle gave a profit margin of US$122-164 per head, which represented about 30-50% of the capital investment.

Where land is not limiting for intensive pasture production, either grazing and or stall feeding can be adopted. A comparative study of both systems to examine potential milk production in Sahiwal X Friesian cows on Leucaena L. leucocephala - Brachiaria decumbens mixed pasture indicated that rotational grazing was better than stall feeding with mean responses of 8577 and 9180 kg/ha/lactation. Supplementation of concentrates at 4 and 6 kg/cow/day further increased milk production to 13323 and 17070 kg/ha/lactation respectively. The net profit per cow with or without supplementation was lower for rotational grazing on account of higher labour cost for the stall feeding system (Table VII).

Factors likely to influence the future of systems combining arable cropping include :

- o Importance of draught animals for crop cultivation and farm transport in small holdings,
- o Feasibility of producing forages on a crop rotation basis,
- o Developments of viable feeding systems based on large amounts of lignocellulosic materials,
- o Feasibility of producing multipurpose animals for milk, meat and draught.

3.1.3. Systems Integrated With Tree Cropping

This system can also be described under the intensive arable system, but it merits separate treatment, especially in view of the area under tree crops (coconuts, oil palm and rubber). The system is especially common in the humid and subhumid regions where there is intensive crop production. Although the system is not new, integration with these tree crops to ensure more complete utilisation for the land has not been given adequate attention.

The advantages of the system are:

- ° Increased fertility of the land via the return of dung urine,
- ° Control of waste herbage growth,
- ° Reduced use of weedicides,
- ° Reduced fertiliser wastage,
- o Presence of shade reduces head stress,
- ° Easier management of the crop,
- ° Distinct possibilities of increases in crop yields, consistent with greater economic including sale of animals and their products.

The potential for this kind of activity is reflected in data on the economic benefits of integrating goats with oil palm cultivation where grazing land (71-135 ha) was made available to the workers for grazing their animals. For the first two years (1980 and 1981), only cattle were owned and grazed; in 1982 and 1983, goats were also introduced in addition to cattle. This was done in view of their economic importance and capacity to supply both meat and milk in the estate. The total cattle and goat populations were both about 80 and 220 animals, respectively. The differences in yield over the four years in favour of the effect of grazing cattle and goats were 2.15-5.16 t fresh fruit bunches per hectare per year with a mean value of 3.51 t of fresh fruit bunches per hectare per year (Table VIII). When translated into the total land area grazed, and sale value per tonne of fresh fruit yield, the economic advantage is substantial.

Factors likely to influence the future of systems integrated with tree cropping include :

- o Dry matter yields under various tree crops,
- o Optimum stocking densities,
- o Feeding behaviour or large and small ruminants under tree crops,
- o Supplementary feeding.

The value of small ruminants is also significant in the wider context of agro-forestry systems. The complementary advantages are forage production, supply of fuelwood, improvement of soil fertility and permanent soil cover, and economic land use.

3.2. Future trends in production systems

Given the patterns of ruminant production systems and the resources being currently utilised to support these, it is suggested that these systems are unlikely to change in the foreseeable future. An example in point concerns future trends in ruminant production systems in South and South East Asia and the South Pacific [46].

It is suggested that changes to the prevailing systems are unlikely and would need to be supported by major shifts in resource use. In any case, accessibility to these and efficient utilisation would be difficult unless returns from the new proposed systems are demonstrably superior. Changes must, therefore, be introduced gradually and need to ensure income stability and low risk. The principal aim should be to make maximum use of the basic feed resources available, which is essentially crop residues or low-quality roughages or both. In addition, delivery systems should be developed for the essential supplementary feeds (leguminous forages, agro-industrial by-products, or other feed concentrates).

Factors likely to influence future ruminant production systems are :

- Market requirements,
- Available feed resources,
- Growth in human populations and consumer preferences

4. DEVELOPMENT STRATEGIES

A number of development strategies and opportunities exist for improving prevailing ruminant production systems, and increasing productivity from ruminants. However, none is more important than two primary considerations: maximum utilisation of the animal genetic resources, and taking full advantage of the available feed resources to identify clearly the objectives of production with economic animal performance.

4.1. Full exploitation of the animal resources

The first task necessitates much greater consideration in the future than in the past, since maximising animal protein production assumes that the animal resources will be fully exploited. Currently, the tendency of development programmes to focus mainly on cattle, is associated with the general neglect of buffaloes, goats, sheep, camels and mules. Many of these resources are numerically very important in the developing countries, but their potential contribution remains to be fully realised. Among these, goats, sheep, camels and mules are particularly neglected and few national programmes give these priority, commensurate with their current and future contribution. Increasing production from them will therefore need much greater attention to their biological attributes, current contribution to farming systems and complementarity to crop production, and interventions which can make an impact on performance, productivity and increased income. Some reorientation of livestock policy and priority needs to be given to ruminant development programmes much more than in the past, failing which current trends will continue without potential realisation of the contribution from the animal resources.

4.2. Increasing the efficiency of feed production and utilisation

The scope for increasing the efficiency of feed utilisation in innovative feeding systems is enormous. The components of this strategy include increased feed production where feasible, inclusion of a wider selection of both traditional and NCFR in dietary formulation especially of crop residues and AIBP, more innovative feeding systems that can sustain year round feeding, and intensive systems of production. Many of these, in combination or together, can make a major impact on current levels of production and are demonstrated in goats [47,48], sheep [49], buffaloes [50] and cattle [51].

In the arid regions where extensive systems prevail, more can be done to increase the productivity of grazing land through improved methods of husbandry, pasture management and introduction of new cultivars. The opportunities for doing so are reflected in projection on potential fodder production (Table IX).

It is estimated that in the Near East about 40 million ha could be used for rain fed fodder production by the use of forage legumes in the traditional wheat/fallow rotation. In this context the outstanding successful development in Syria, of the ancient and traditional system of grazing control, the hema, merits special mention. It includes inter alia introducing Atriplex spp., planting fodder trees and creating lamb fattening cooperatives. By comparison, in the drought prone areas in western India, the introduction of Cenchrus ciliaris and Lasiurus sindicus increased DM yield from 0.4 t - 3 t/ha/annum [53].

The system ensures that the members agree to a maximum holding of 100-125 sheep for family, according to the carrying capacity of the area allocated to the cooperative. The benefits are reduced pressure on the ranges, increased offtakes from the land and socio-economic benefits. The animals purchased for fattening are usually young males between 6-16 months age, weighing 25-40 kg live weight, given 1.5 kg of feed per animal per day, and finally sold for a profit at about 53-60 kg live weight. Up to 1981, it has been reported that the number of cooperatives has increased to 55 having 4371 members and involved 1.5 million sheep annually. In Syria, this has involved two million sheep annually [54].

In the more humid regions of the developing countries such as in Central America and the Caribbean, East and West Africa, and throughout South and South East Asia where mixed crop-animal systems are more common, fodder production on available lands such as in fence lines, alley farming, use of rice bunds, integration with perennial crops and in agro-forestry systems offer considerable opportunities.

Of particular relevance in this context is the potential value in feeding systems of a wide variety of tree fodders and include inter alia Acacia (Acacia spp), calliandra (Calliandra calothyrsus), ficus (Ficus spp.), erythyrna (Erythyrna variegata), gliricidia (Gliricidia maculata), leucaena (Leucaena leucocephala), neem (Azardirachta indica) and sesbania (Sesbania grandiflora). Many of these fodders have potential value especially as supplements in feeding systems for ruminants, and this value has recently been reviewed in buffaloes [55] and sheep [56]. Table X summarises the position with buffaloes in which it has been consistently demonstrated that reduced cost of feeding has been associated with no loss in performance compared to feeding concentrate exclusively.

Crop residues, AIBP and NCFR offer much opportunity for promoting intensive systems of production especially in close proximity to where they are produced. Table XI summarises examples by location in the Asian region.

Concurrent with these strategies in the need for parallel attention to improved health measures, on-farm application of appropriate technology that can deliver accumulated and potentially valuable technology developed on-station, and the measurement of social and economic progress consequent to the impact of improving individual ruminant production systems. These approaches together can provide for increased efficiency in the use of available resources and improvements to ruminant production systems throughout the developing countries.

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TABLE I ANIMAL RESOURCES IN THE DEVELOPING COUNTRIES [2,3,4]

Species	Population (10^6)	As % of total world population (%)	Annual rate of growth (1975-1985, %)
I. HERBIVORES			
Buffaloes	137.7	99.5	Static
Cattle	855.0	67.2	1.2
Goats	463.2	94.1	1.5
Sheep	601.2	52.5	1.4
Asses	38.8	95.8	-ve
Camels	17.2	98.9	2.8
Horses	42.6	65.4	0.8
Mules	14.7	97.4	2.9
II. NON-RUMINANTS			
Chickens+	4872.0	54.6	3.2
Ducks+	158.0	81.0	2.4
Pigs	486.9	59.2	2.6

+ Million heads

TABLE II. ADAPTATION OF RUMINANTS AND EQUINES [1]

Species	Arid/Semi-arid zone	Wet zone
Water buffaloes (*Bubalus bubalis*)		Larger size (400-600 kg) Stocky Low hair density Limited sweat glands (140-150/cm^2) Light to dark colour Grey skin to reduce solar and radiant heat Very indented epidermis Strong pigmentation
Cattle (*Bos indicus*)	Taller Large size (350-450 kg) Loose skin and appendages Able to walk long distances	Shorter, compact body Medium size (300-500 kg) Thicker skin Higher hair density Sparse pigmentation More sweat glands (800-1500/cm^2)
Goats (*Capra hircus*)	Large size (30-50 kg) Tall (70-100 cm height) Long legs and ears Soft spongy hooves White, black or brown colour, shiny skin Short hair covering Prehensile lips Fat reserves less than sheep (mainly visceral) Survivability greater than sheep	Small size Short (50-65 cm (height) Short legs and small ears Mainly black or brown coat Less shiny skin
Sheep (*Ovis aries*)	Large size (30-50 kg) Tall (60-80 cm height at withers) Long legs Thick hooves Cream to brown colour Fibre covering High fat reserves	Small size (10-25 kg) Short legs and small ears Coarse wool more matted
Camels (*Camelus dromedarius*)	Long legs Long neck Distinct single hump Split upper lip Nostrils almost closed	
Equine (*Equus asinus*)	Generally small in size Relatively smaller stomach	Smaller

TABLE III. FEEDING BEHAVIOUR AND METABOLISM OF RUMINANTS AND EQUINES [1]

Species	Arid/Semi-arid zone	Wet zone
Water buffaloes		Grazer (3-5 km/day) Slower rumen movements Use coarse roughages more efficiently Superior N retention
Cattle	Grazer (3-5 km/day) More active Able to walk long distances Dietary N less well digested	Utilises forages efficiently With coarse roughages, longer retention time in <u>Bos indicus</u> cattle
Goats	Browser (8-12 km/day) Bi-pedal stance More active Selective feeding More discerning taste Relishes variety in feeds Utilises coarse roughages more efficiently Recycling of urea greater	Daily consumption of dry matter up to 6% BW
Sheep	Grazer (3-5 km/day) More sedentary Less discerning taste Recycling of urea less Use coarse roughages less efficiently	Preference is for grass Daily consumption of dry matter up to 3% BW
Camels	Grazer and browser (15-25 km/day) High digestive efficiency for cellulose Less selective Higher efficiency of N utilisation Very tolerant to salt Feeding and digestion unimpeded by water restriction	
Asses Horses Mules	Grazer Lower digestive efficiency Digestion mainly in the colon No rumination or eructation Faster rate of passage	

TABLE IV. EXTENT AND DISTRIBUTION OF PERMANENT PASTURES, FORESTS AND WOODLANDS AND RUMINANT LIVESTOCK [4]

Region	Permanent pastures (10^6 ha)+	Forest and woodland (10^3 ha)+	Ruminant livestock units (10^6)++
Developing market economies			
Africa	631.2	645.7	138.4
Asia and the Far East	109.8	220.5	356.3
Latin America	512.7	928.8	253.2
Near East	267.6	95.2	67.0
Total	1521.3		814.9
Asian centrally planned economies	409.8	188.6	100.5
Total developing countries	1931.1	2078.8	915.4
World total	3170.8	4086.6	1319.6
As % of world total:	60.9	50.9	69.4

\+ Refer to 1985 data

++ Conversion Factors: Buffalo 1.0, Cattle 0.8, Goats and Sheep 0.1

TABLE V. THE AVAILABILITY OF NON-CONVENTIONAL FEED RESOURCES IN ASIA AND THE PACIFIC [40]

Category	Availability (10^6 t)
Field Crops	230.3
Tree Crops	7.4
Total	237.7+

+ Represents 46.3% of the total availability from field and plantation crops

TABLE VI. TRENDS IN FEED BALANCES IN INDIA (ADAPTED FROM [41])

Nutrient	1970			1984		
	Availability[a]	Requirement[b]	% Deficit	Availability	Requirement	% Deficit
Energy (10^7 Mcal ME)	6162.8	9877.9	37.6	7399.4	10933.5	32.5
DCP (10^4 mt)	113.2	297.8	61.9	135.1	344.0	54.0

[a] ME - Metabolisable energy; DCP - Digestible crude protein

[b] Of herbivores (buffaloes, cattle, goats, sheep, asses, yaks and chauri) and non-ruminants (poultry and pigs)

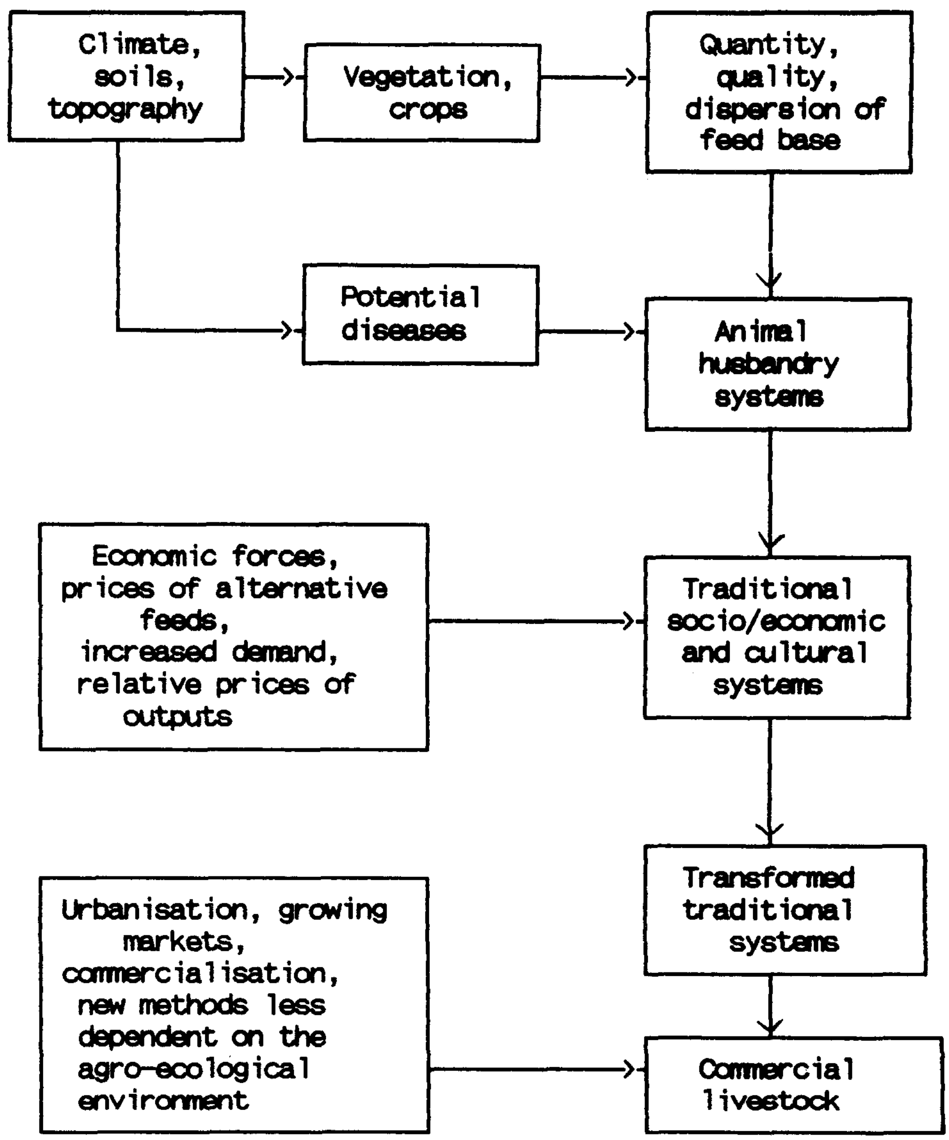

FIGURE 1. GENESIS OF LIVESTOCK SYSTEMS

TABLE VII. MILK YIELD IN SAHIWAL X FRIESIAN COWS AND COSTS OF MILK PRODUCTION IN TWO SYSTEMS OF PRODUCTION IN MALAYSIA [45]

	Rotational grazing			Cut-and-carry+
Conc. supplementation :	0 kg	4 kg	6 kg	0 kg
Total milk yield (kg/cow/lactation)	1712	2733	3269	1417.70
Total cost/animal ($)	573	1061	1305	732.00
Cost/kg of milk ($)	0.34	0.39	0.40	0.52
Gross income at 65 cts/kg milk	1112.8	1776.5	2124.85	921.50
Production cost ($)	528.1	1065.9	1307.6	737.20
Net profit/cow ($)++	530.7	710.6	817.3	184.30

+ L. leucocephala and B. decumbens forages
++ Malaysia (1US$ = 2.70 Malaysian Ringgit)

TABLE VIII. THE EFFECT OF MIXED CATTLE AND GOAT GRAZING ON THE YIELD OF FRESH FRUITS IN OIL PALM CULTIVATION IN MALAYSIA [39]

Year	Grazed area (Yield of fresh fruit bunches/ha/yr, mt)	Non-grazed area (Yield of fresh fruit bunches/ha/yr, mt)	Difference (Fresh fruit bunches ha/yr, mt)
1980	30.55 (C)+	25.61	4.94
1981	17.69 (C)+	15.87	1.82
1982	25.12 (C + G)++	22.97	2.15
1983	23.45 (C + G)	18.29	5.16
Mean	24.20	20.69	3.51

\+ C = Cattle

\++ C + G = Cattle + Goats

TABLE IX. FODDER PRODUCTION, 1980 AND 2000[1] [52]

Region	1980				2000			
	Area (10^6 ha)	Yield (tons/ha)	Production (10^6 +)	%	Area (10^6 ha)	Yield (tons/ha)	Production (10^6 +)	%
90 developing countries	27.2	4.8	131.4	100.0	46.8	6.6	307.0	100.0
of which:								
Africa	1.1	4.7	5.1	3.9	3.0	5.6	17.0	5.5
Far East	10.8	4.9	53.3	40.6	19.5	7.4	145.0	47.2
Latin America	12.6	4.2	53.3	40.5	18.8	5.0	93.5	30.5
Near East	2.7	7.3	19.7	15.0	5.5	9.4	51.5	16.8
Low-income countries	11.0	4.9	54.3	41.3	20.2	7.4	149.0	48.6

[1] Green fodder in dry matter equivalent

TABLE X. RESULTS OF ECONOMIC BENEFITS OF FORAGE SUPPLEMENTS IN DIETS FOR BUFFALOES AND CATTLE [55]

Feeding regime	Forage supplement	Species	Location	Response	Result	Reference
Wheat straw* + conc.	Lucerne + berseem	Buffaloes	India	Milk	Reduced cost/kg SCM milk	Gupta et al., (1983)
Concentrates	Berseem hay	Buffaloes	India	Milk	Reduced cost/kg milk	Chauhan and Chopra (1984)
Rice straw+	Gliricidia or Leucaena	Buffaloes	Sri Lanka	Milk	Increased margin over costs	Perdok et al., (1983)
Wheat straw* + conc	Leucaena	Calves	India	LW	Reduced cost/kg LW gain	Akbar and Gupta (1985)
Concentrates	Leucaena	Buffaloes	India	Milk	Reduced cost/kg FCM milk	Dharmaraj et al., (1985)
Oat silage + conc	Berseem hay	Buffaloes	India	Milk	Reduced cost/kg milk	Chauhan (1986)
Rice straw++	Leucaena	Cattle	Thailand	LW gain	Reduced cost/kg LW gain	Cheva-Isarakul and Potikanond (1985)
Rice straw* + dried poultry litter + conc	Leucaena leaf meal	Cattle	Philippines	LW gain	Reduced cost/kg LW gain	Trung et al., (1987)
				Milk	Reduced cost/by milk	

* Untreated wheat straw
\+ Urea-treated rice straw
++ Urea-treated or untreated rice straw

TABLE XI. POTENTIALLY IMPORTANT EXAMPLES OF PRIMARY FEEDS INTENSIVE UTILISATION IN THE ASIAN REGION [57]

Type of primary feed	Location	Species
Bananas	Philippines	Beef cattle, ducks
Cassava		
- Leaves	Thailand, Indonesia Philippines	Beef cattle, goats, and swamp buffaloes
- Pomace	Thailand, Indonesia Philippines	Pigs, ducks, lactating cattle and goats
Maize stover	Philippines, Indonesia	Beef cattle, swamp buffaloes, goats and sheep
Oil palm		
- POME, palm press fibre, palm kernel cake	Malaysia	Beef cattle, swamp buffaloes
Rice bran	Thailand, Indonesia Philippines	Pigs, poultry and lactating ruminants
- Straw	Thailand, Sri Lanka Philippines, Thailand	Beef cattle and swamp buffaloes
Sugar cane		
- Tops, bagasse	India, Pakistan Thailand	Beef cattle and swamp buffaloes
Wheat		
- Bran	India, Pakistan	Pigs, poultry lactating ruminants
- Straw	India, Pakistan	Beef cattle and swamp buffaloes