

Chapter 6

Feed resources for ruminants

Treatment with urea, feeding of multi-nutritional blocks and high-offer level feeding are the interventions most likely to increase the potential nutritive value of fibrous crop residues. The exploitation of this potential will be determined by the level of supplementation with "by-pass" nutrients, especially protein. The optimum level of supplementation will depend on the cost of the supplement and the added value of the increase in production.

Multi-purpose crops which provide both feed and fuel will increasingly find a role as the demand increases for renewable sources of energy and increasing emphasis is put on the need for farming systems that have positive effects on the environment, especially the content of organic matter in soils.

LIVESTOCK SYSTEMS BASED ON CROP RESIDUES

This system will have its application in regions of very high population density where crop production is the predominant activity and the major feed resources are the residues and by-products of food crops.

STRAWS FROM CEREAL CROPS

Balance of nutrients

Crop residues and fibrous agro-industrial by-products are characterized by low to moderate digestibility, and low levels of nitrogen, protein and minerals. Classical temperate country wisdom diagnosed energy density as the first constraint and the proposed solutions were supplementation with energy-rich feeds (e.g., cereal grains, root crops or specialist forage crops for feeding directly or after ensiling). Even when it was recognized that these strategies were inappropriate and uneconomic, the classic approach persisted and scientists sought solutions through chemical treatment of the fibrous feeds to improve digestibility.

There is a definite place for chemical treatment of fibrous crop residues but the first step must be to correct the balance of nutrients, since this is the first constraint to productivity of livestock fed these resources. The system involves:

- Feeding the rumen microbes
- Feeding the animal a source of by-pass protein

Feeding the rumen microbes

There are three approaches to providing the rumen microbes with a better array of nutrients, including fermentable energy (Figure 6.1):

- Supply critical nutrients (missing in the residue) by means of a multi- nutritional block (Leng, 1990).
- Facilitate selection by the animal of the more digestible components of the residue by offering at least twice the amount it can be expected to consume (Owen, 1994).
- Saponify partially the phenolic linkages with acids or alkalis.

The choice of method will be determined by the relative availability of the residue, alternative end uses (e.g., as fuel or as roofing material), the cost of the urea (or ammonia) and the convenience of the technology.

Figure 6.1. Strategies for making better use of fibrous crop residues.

THE ALTERNATIVES

■ SELF SELECTION

- Offer **TWICE** the expected intake
- Free access to multinutritional block

■ AMMONIFICATION WITH UREA

- 5% urea in straw DM
- 30–50% water

 In both cases feed:

- 0.5 kg/d rice polishings (or cottonseed cake)
- 2–3 kg/d green feed (or 3 hr/d grazing)
 (preferably legume tree foliage)

Provision of multi-nutrient blocks has had the widest impact (Sansoucy, 1995). The selection approach has advantages when there is a need for feed and fuel, since the parts of the residue rejected by the animal are those which are drier and more lignified and therefore of higher fuel value (Owen, 1994).

Saponification with ammonia accomplishes two tasks. It supplies ammonia and also energy (by breaking phenolic linkages in the cell wall) to the microbes.

Multi-nutrient blocks

Fibrous crop residues and agro-industrial by-products are the typical diet of ruminant animals in most tropical countries and often are the only feed resource in extended dry seasons. These feeds are characterized by an imbalanced array of nutrients, of which fermentable nitrogen is usually the first limiting; organic matter digestibility is also usually below 50%. The use of solidified blocks containing urea, minerals (and often rumen by-pass nutrients), pioneered by Professor R.A. Leng of the University of New England, Armidale, Australia, to supplement these fibrous feed resources has been outstandingly successful in a large number of countries. The FAO Feed Resources Group, with the help of the FAO Technical Cooperation Programme, has initiated projects in more than 60 countries using this technology (Sansoucy, 1986).

Table 6.1. Formula for multi-nutrient blocks containing sugar cane scums (or juice) and with addition of clay to improve gelling characteristics (Source: SIDA-MSc, 1994).

Ingredient	% Fresh weight	% Dry weight
Scums*	46	16
Clay (dry)	9	14
Urea	4.5	7
Cement	4.5	7
Salt	2.3	3.5
Maize bran	15	23
Sunflowerseed hulls	18	28

* Juice and flocculated protein and minerals

Typical results from providing multi-nutrient blocks are given in Figure 6.2, taken from a series of villages in India as part of the NDDB (1982) programme. The major problem with the technology has been the

difficulties in some situations of making blocks of sufficiently hard consistency to limit intake and ensure there will be no risk of urea toxicity which might occur if intake of the block is excessively high. Molasses, which is the usual basis of the multinutritional block, is also not always available or it may be too expensive through high transport charges.

High-offer feeding

Typical results using the high-offer feeding system to facilitate selection are in Figure 6.3. The data show that lambs almost doubled their rate of growth when the offer level of sorghum stover was increased by a factor of between 2 and 3. This method is especially appropriate for the residual pressed sugar cane stalk (after partial juice extraction) (Figure 5.9).

Ammoniation

Alkali treatment of fibrous crop residues is well researched (Sundstøl and Owen, 1984) and the possibility of using urea as a source of ammonia (Dolberg *et al.*, 1981) led to expectations of rapid implementation in many developing countries which, however, have not been realized (Owen and Jayasuriya, 1989) for several reasons (Dolberg, 1992). Too much attention to treatment technique *per se*, and too little to supplementation strategies aimed at employing biologically effective supplements available to the farmers, are some of the explanations. Unsupplemented ammoniated straw supports production levels far below the level potentially made available by the increase in digestibility and intake due to ammoniation (Preston and Leng, 1987). Low levels of production may not earn farmers sufficient income to pay for the ammoniation treatment and, consequently, they lose interest and the technology is not taken up.

Figure 6.2. Introduction of multi-nutritional blocks in Indian villages led to significant increases in milk production (Source: Kunju, 1986).

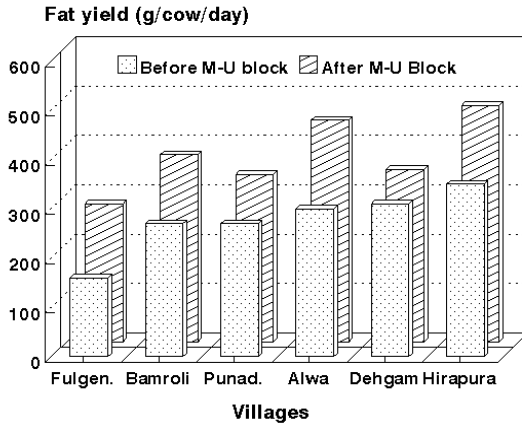
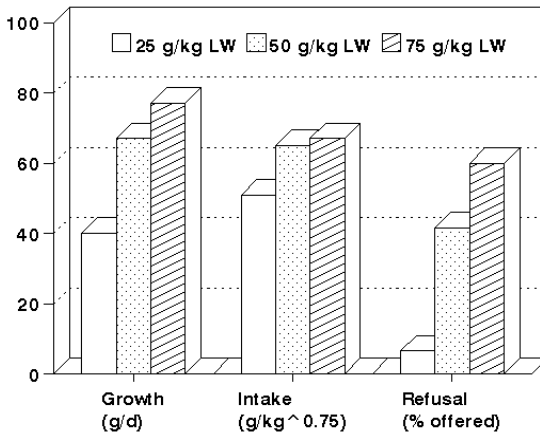


Figure 6.3. Given the opportunity to select, sheep will consume the most nutritious parts of a feed (sorghum stover in this trial) and respond with almost a doubling of performance (Aboud *et al.*, 1990).



Lack of feedback from extension or no communication at all between research and extension can be mentioned as some of the other reasons for lack of impact of new technologies. There has been insufficient research with a farmer's perspective in the area of crop residue utilization although good extension work must be based on precise knowledge.

A large-scale FAO/UNDP-supported project in China has demonstrated that, provided "by-pass" protein supplements are available and used (in this case cottonseed cake), then the economic and political impact can be huge (Finlayson *et al.*, 1994). Typical data for cattle fed with ammoniated (urea treatment) wheat straw in this project were given previously in Figure 5.12.

It is generally believed that the response to ammoniation has two components: an increase in digestibility due to partial saponification of the lignin-cellulose-hemicellulose linkages, and a greater feed intake arising from the greater supply of ammonia to the rumen micro-organisms.

Ammonification supplies the nitrogen needs of rumen microbes as well as increasing digestibility; however, it is an expensive way of supplying the nitrogen, as the level required for effective treatment of the residue is some 50% greater than what is needed by the rumen microbes. An important economic issue, which has not been adequately evaluated, is the relative effectiveness of ammoniation using urea as compared with supplementing untreated straw with a molasses-urea block.

The data in Table 6.2 show that ammoniation gave slightly superior results. However, the straw on both treatments was fed at normal levels (i.e., some 15% above intake). This work must be repeated but with high-offer level feeding of the straw complemented with the blocks.

Another issue that requires clarification is the optimum level of urea for effective ammoniation. The usually recommended level is 5% of the dry weight of the residue; yet researchers in Vietnam contend that a lower urea level of 2.5% urea complemented with 0.5% of calcium hydroxide gives almost as good a biological response and is more economical (Bui van Chinh, unpublished observations). As the price of urea is tending to rise, as Governments in developing countries reduce agricultural subsidies, it is opportune to examine more closely the possibility of using lower inputs.

The ammoniation process is described in Chapter 7.

Table 6.2. Effect of ammoniation of rice straw or supplementation with molasses-urea block (MUB) on performance of growing heifers during consecutive periods in summer (150 days) and winter (90 days) in Hanoi province (Source: Bui van Chinh *et al.*, 1994).

	Ammoniated straw	Untreated straw + MUB
Initial wt (kg)		
Summer	156	156
Winter	224	210
Mean	190	183
Final wt (kg)		
Summer	224	210
Winter	264	243
Mean	244	227
LWt gain (kg/d)		
Summer	0.453	0.360
Winter	0.444	0.367
Mean	0.449	0.363
Intake straw DM (%LWt)		
Summer	1.62	1.1
Winter	1.7	1.17
Mean	1.66	1.17
Total DM (%LWt)		
Summer	2.63	2.34
Winter	2.27	2.14
Mean	2.47	2.22
Feed DM conversion		
Summer	11.3	11.9
Winter	12.7	13.3
Mean	11.8	12.7

Strategic supplementation

As with untreated crop residues, appropriate supplementation is the key to securing adequate animal response (see Figure 5.12). Mostly protein-rich by-products from oilseed or cereal grain milling have been used as the source of "by-pass" protein (Preston and Leng, 1984). However, there is much potential in the use of leaves from legume trees for this purpose (Figure 6.4).

The experience in India by the National Dairy Development Board in their rural development programme "Operation Flood" affords an example of the impact of replacing inappropriate "temperate country technologies" (supplementing crop residues with "balanced dairy concentrates") with appropriate technologies (multi-nutrient blocks and "by-pass" protein) based on the concepts of strategic supplementation of rumen microbes and the animal (Leng, 1984).

Stovers from maize and sorghum

There are few reports of uptake by farmers of the ammoniation technique applied to stovers derived from maize, sorghum and millet, although technically it has been shown to be feasible but more difficult than for straws, due to the bulkiness of the material (Jayasuriya, N., personal communication). The component parts of these residues can differ quite widely in digestibility and it would seem more appropriate perhaps to use the "high-offer" feeding system to facilitate selection of the more digestible components rather than urea treatment.

Correct supplementation of the untreated maize stover can lead to a doubling of live weight gain as demonstrated in Figure 6.5. The effects can be explained almost entirely by improvements in rumen function brought about by supplementation with urea and small amounts of grass (see Chapter 5).

Residues from plantains and bananas

In some tropical regions, plantains and bananas are the staple of the human diet (e.g., in the Kilimanjaro region of Tanzania). The principles for using these as the basis of the diet of ruminant animals are the same as for cereal stovers. The bulk of the biomass residue is in the pseudo-stem which is of low nitrogen content but highly digestible, while the protein in the leaf lamina appears to be largely bound to tannin-like substances giving it a low digestibility (Kimambo and Muya, 1991). Therefore the supplements needed are:

- Multi-nutritional blocks to provide urea and minerals;
- A source of by-pass protein (from oilseed meals, rice polishings or as leaves from legume trees).

Figure 6.4. Leaves from the leguminous tree *Leucaena leucocephala* (2 kg/d) were as effective as rice polishings (500 g/d) in stimulating growth of cattle fed ammoniated rice straw (Source: CIPAV, 1987).

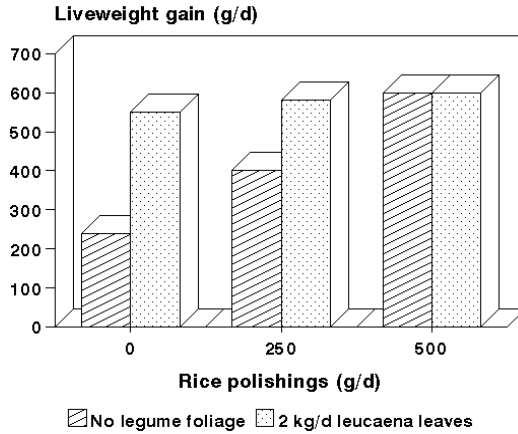
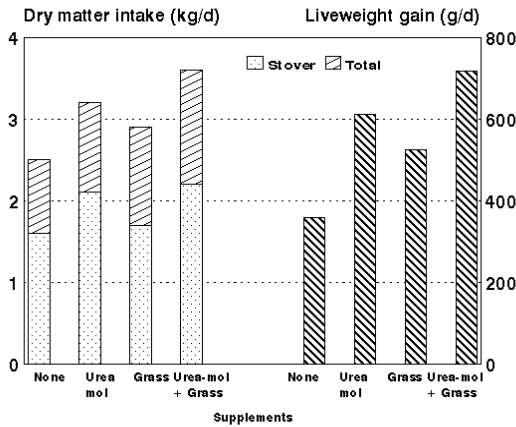


Figure 6.5. Supplements of urea and grass markedly increase growth rates of cattle fed untreated maize stover and cottonseed cake (Source: Ocen, 1992).



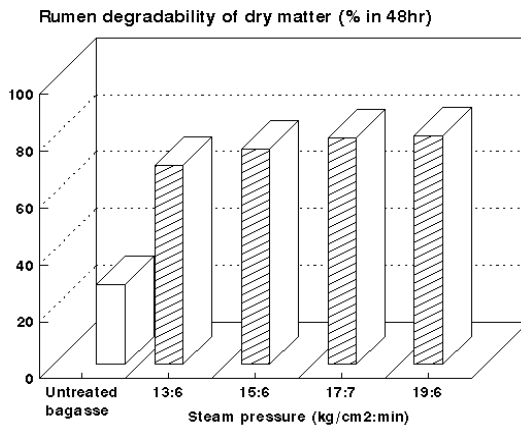
* All treatments had 1 kg/d of cottonseed cake

FIBROUS RESIDUES FROM INDUSTRIAL AND ARTISAN CANE SUGAR MANUFACTURE

Sugar factory bagasse

The residual fibre after industrial separation of sugar by repeated extraction (see Figure 7.1) is described as "factory" bagasse to distinguish it from that produced in simple 2- or 3-roll crushers (*trapiches*) which also contains residual juice (from 20 to 30% of the dry matter). Factory bagasse contains about 45% cellulose, 35% hemicellulose and 10% lignin. The raw material has a very low digestibility (about 30%). However, dramatic improvements can be brought about by high pressure steam (13 kg/cm²; 200°C) which, through acid hydrolysis (acetic acid is generated in the process), solubilizes the hemicellulose component (Wong *et al.*, 1974; Figure 6.6).

Figure 6.6. High pressure steam is an effective way of increasing the digestibility of sugar cane bagasse (Source: Basile and Machado, 1990).



Steam hydrolyzed bagasse must be supplemented with rumen and by-pass nutrients (Naidoo *et al.*, 1977; Machado, 1989) after which it supports quite high levels of production in fattening cattle (Osorio *et al.*, 1990; Basile and Machado, 1990). This technology has been applied commercially in intensive cattle fattening in Colombia (CIPAV, 1987)

and Brazil (Machado, 1989). The Colombian programme has been discontinued in favour of processing the bagasse for paper. However, in Brazil where the integration of sugar and alcohol production results in large surpluses of bagasse it is reported that more than 200,000 cattle are being fed with steam-hydrolyzed bagasse (Machado, P., personal communication). The technology has also been introduced into India (Rangnekar, personal communication).

Alkaline hydrolysis of factory bagasse with sodium hydroxide is also an effective method of upgrading the bagasse and has been employed in Cuba on a large scale (Martin, 1987), although mostly with the short fibre fraction (*bagacillo*) which remains when the larger fibres are separated out as raw material for paper production. The method is relatively costly, as well as polluting because of the large quantities of sodium hydroxide required. It is not a sustainable technology and therefore is not recommended.

Rising oil prices and increasing awareness of environmental issues will almost certainly favour the future use of bagasse as fuel with electricity generation as the major output, in co-generation schemes (Ogden *et al.*, 1990) which will also produce sugar, alcohol and/or molasses from the cane juice (Preston and Echaveria, 1991).

Sugar cane tops and pressed sugar cane stalk ("trapiche" bagasse)

The fibrous residues derived from farm scale fractionation of sugar cane (Chapter 7), and from artisan production of "*panela*" or "*gur*", which have potential for feeding to herbivores are:

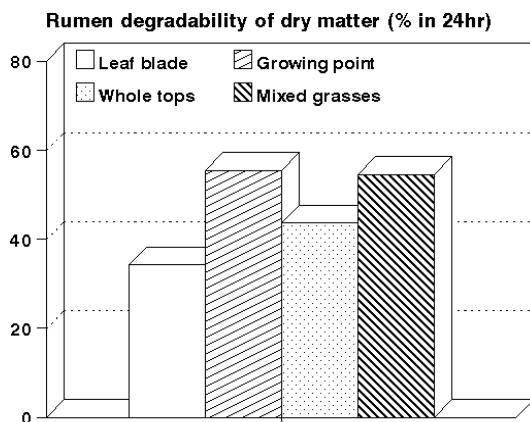
- The cane tops
- The pressed stalk

Cane tops

When complemented with rumen and "by-pass" supplements, cane tops will support liveweight gains of the order of 700 g/d (Ferreiro *et al.*, 1977) in fattening cattle and 3,000 litres lactation yield in milking animals (Boodoo *et al.*, 1990a). It is important to encourage selection by offering quantities of tops which exceed by at least 50% the expected intake. Under these circumstances the animal has been observed to preferentially select the growing point of the cane and to reject in large part the leaf blade (Boodoo *et al.*, 1990b).

The justification for this selection can be seen in the data for dry matter degradabilities in rumen nylon bags (Figure 6.7). The growing point has a much higher rate of degradability than the leaf blade, and is comparable to that of nutritious grass.

Figure 6.7. Digestibility is higher for the growing point of the sugar cane tops than for the leaves (Source: Boodoo *et al.*, 1990b).



The African hair sheep appears to be a particularly appropriate target animal for utilizing the cane tops. Since late 1989, some 100 breeding ewes and their progeny have been managed in full confinement on this system in Colombia. They have free access to cane tops, multinutritional blocks and a 9:1 mixture of poultry litter and rice polishings. The advantages of sheep in such a system are:

- Low investment in animals and housing (renewable bamboo poles and palm leaves). No concrete is needed as the rejected fibrous components of the feed are used as built-up litter.
- The sheep are highly resistant to common diseases and the housing system reduces risks of endo- and ecto-parasite infections.
- Sheep are selective feeders and adapt more readily to confinement than goats.

- Sheep production is especially suitable for cash-poor smallholder farmers since:
 - Investment risk is distributed among many animals rather than in few, as would be the case for cattle.
 - A lamb can be consumed by a family in 1 or 2 days, avoiding need for refrigerated storage, or it (or a sheep) can be sold for cash. None of this is possible with cattle.

Pressed sugar cane stalk

The pressed stalk which remains after a single-pass extraction of the cane stalk through a 3-roll mill (or 2 to 3 passes in a mill with only 2 rolls) contains some 20-30% of soluble sugars in the dry matter. The associated cell wall material is, however, of low digestibility as it has the same composition as sugar factory bagasse which is only about 28% digestible (Wong *et al.*, 1974).

The pressed stalk is particularly appropriate for manipulating via the high-offer level feeding system (Figure 5.9). When it is coarsely chopped and offered at 2 to 3 times expected intake, it is relatively easy for cattle and sheep to select the more digestible component (the soft pith, rich in sugar) (Vargas *et al.*, 1994). This feed should be supplemented with multi-nutritional blocks, fodder tree foliages (about 2-3 kg fresh material per 100 kg liveweight) and restricted amounts (500 g/day) of a supplement rich in by-pass protein such as rice polishings. Growth rates of F1 crossbred (Holstein x Zebu) from weaning to point of calving on this feeding system have been of the order of 500 g/day (Rodriguez, L. and Cuellar, P., 1994, Unpublished data). Fattening bulls have gained at similar rates when supplemented with *Gliricidia sepium* foliage, a 20% urea block and 1 kg/day of a mixture of poultry litter and rice polishings (Molina, C., 1994, personal communication).

LIVESTOCK SYSTEMS BASED ON CROPS WITH HIGH YIELDS OF BIOMASS

The concept of tropical biomass and integrated farming systems as the basis of sustainability

The essential features of a strategy to optimize production and use of natural resources is to ensure that the biomass can be processed in a way that will contribute efficiently to provision of human food, animal feed,

chemicals and energy. The animal feed element must be further defined so as to take account of the differing needs of monogastric and herbivorous animals.

The corollary to fractionation is integration, since in order to efficiently utilize the different components of plant biomass (e.g., soluble cell contents, cell wall material with different degrees of lignification), it is essential to tailor end uses accordingly. Thus it makes no sense to feed sugar cane juice or bananas to herbivorous animals when much higher biological efficiencies can be obtained by using them as the basal diet of pigs and poultry. Similarly, it will be more economical and ecologically advantageous to convert sugar cane bagasse, tree branches and highly lignified crop residues into fuel than to process them for feeding to herbivorous livestock. Wherever possible the farming system therefore should offer opportunities for both monogastric and herbivorous livestock production, and for generation of energy.

Thus, although it is feasible to feed a wide range of tropical high-biomass crops, including whole sugar cane, to ruminant livestock, such measures should be viewed as short term solutions. The correct long term approach must be to fractionate the crop according to the most profitable end-product possibilities and to manage and use them always with the aim of optimizing the productivity of the whole farming system.

SYSTEMS BASED ON SUGAR CANE AND ITS DERIVATIVES

Strategy for use of sugar cane as animal feed

An important advantage of sugar cane as a multi-purpose crop is its beneficial effects on soil fertility (Figures 6.8 and 6.9). Thus in the acid-sulphate soils region in the Mekong Delta in Vietnam sugar cane is grown in short rotation with rice (8 months cane: 3 months rice) precisely because the rice crop (for food security) would have very low yields if it were not preceded by the sugar cane. In addition, the farmers inter-cropped the cane during the first 3 months with legume beans; the reason was that, in association with cane, there was negligible pest damage on the beans, compared with growing the beans as a single crop.

Figure 6.8. Effect on soil fertility parameters of removing or returning sugar cane leaf trash to the soil (Source: Phan Gia Tan, 1994).

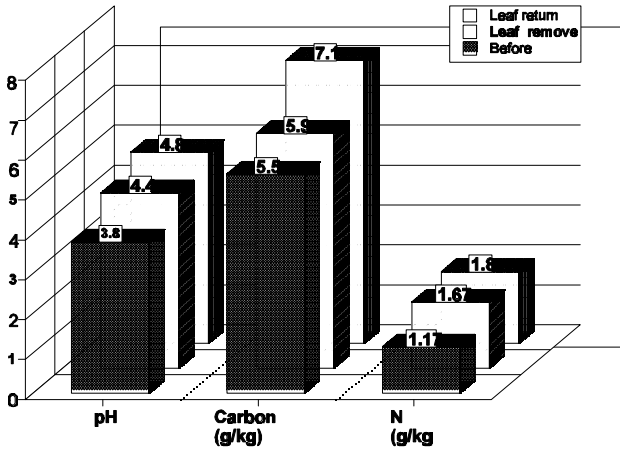
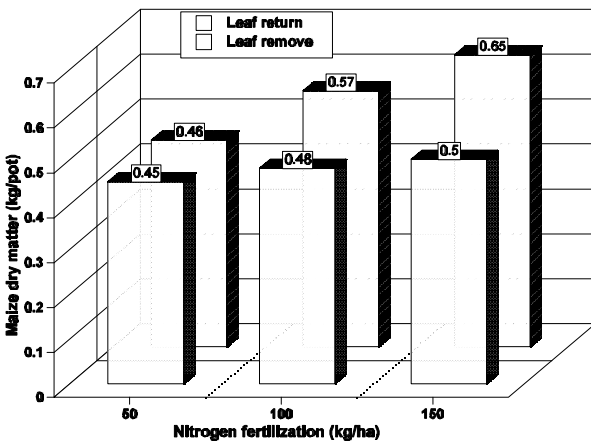


Figure 6.9. Effect on soil fertility (measured as growth of maize plants in soil samples taken from experimental plots) of removal or return of sugar cane leaf trash (Source: Phan Gia Tan, 1994).



Maintenance and, even better, the capacity to increase soil fertility will become increasingly important in the choice of crop rotations. Thus, sugar cane has potentially many advantages as a component of cropping systems in the tropics. Management systems should be aimed to exploit these potential assets.

In this context the following criteria can serve as a guide in managing cropping systems based on sugar cane:

- Selection of varieties which optimize yield of biomass, pest resistance and ease of fractionation, and not necessarily percentage of sucrose.
- Intercropping with legume grain crops to provide supplementary protein (e.g., soybean and peanuts), to increase biodiversity and improve soil fertility.
- Alley cropping with different species of multi-purpose trees (e.g., 20- 30m strips of trees alternating with the cane) to provide additional protein-rich feed, fuel and timber, erosion control and biodiversity.
- Fractionation (see Figure 7.4) as the preferred processing method to optimize use of the different components.
- Use of the tops and the pressed cane stalk as feed for ruminants.
- The juice for pigs and water fowl.
- The pressed cane stalk for fuel (with or without selection by ruminant animals).
- The leaf trash as an energy source for soil micro-organisms.

Chopped whole and derinded sugar cane for ruminants

The idea of separating the cane stalk into rind and sugar-rich pith, using sophisticated wood processing technology, was promoted strongly by Canadian developers (Tilby, E. and Miller, R., cited by Lipinsky and Kresovich, 1982) in the late '60s and early '70s. The aim was to transform the rind into paper and compressed board and use the residual pith as animal feed. Although theoretically superior to chopped whole cane (DM digestibility of 70 compared with 62%; Montpellier and Preston, 1977), in practice the advantages of the derinded cane over chopped whole cane were insignificant biologically (Figure 5.10) and were more than outweighed by the high investment and operating costs of the derinding equipment.

Research on chopped whole cane as ruminant feed emphasized the

important role of urea (Alvarez and Preston, 1976), of by-pass protein, starch and oil (Ferreiro *et al.*, 1977; Preston *et al.*, 1976; Elliott *et al.*, 1978) and of using sugar cane with high content of sugars (Alvarez and Preston, 1976). Rice polishings - which are relatively rich in well balanced amino acids, starch and oil - have a physical form which facilitates almost complete escape from the rumen (Elliott *et al.*, 1978). They have proved to be the most effective supplement when sugar cane and its derivatives are fed to ruminants (CIPAV, 1987). They are widely available in most tropical countries.

The unique characteristics of sugar cane enabling it to reach its maximum nutritive value in the dry season (Alvarez and Preston, 1976), has made it an attractive complement to pastures which are low in both quantity and nutritive value in the dry season. Restricted feeding of foliage from leguminous trees (*Leucaena* and *Gliricidia*) has proved to be a cost-effective partial replacement of the rice polishings in these systems (Alvarez and Preston, 1976; Molina, C., 1994, personal communication).

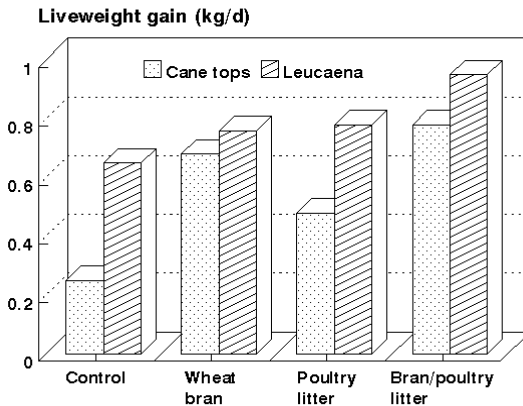
However, as has proved to be the case with final "C" molasses, so with whole sugar cane, low profitability of beef and milk production has led to new developments in its use which in the long term promise to bring greater cost benefits. In most situations today, fractionation of the cane stalk into juice and residual pressed stalk for use in integrated farming systems, is proving to be a more attractive strategy with which to face the challenge of making more efficient and sustainable use of tropical biomass resources.

Final molasses

Methods for using high levels of "C" or final molasses as the basis of intensive cattle fattening were developed in Cuba in the late '60s (Preston *et al.*, 1967; Preston and Willis, 1974). These first approaches used fish meal as the source of by-pass or escape protein (Figure 4.2). This was the first large scale commercial application of the concept of by-pass protein feeding, hypothesised originally in 1963 (see Whitelaw and Preston, 1963).

Subsequent work focused on use of cheaper alternatives and led to the idea of supplying both roughage and by-pass protein in the form of crop and tree foliage (e.g., Figure 6.10 and Preston and Leng, 1987).

Figure 6.10. Fattening steers on molasses-urea; *Leucaena* vs. sugar cane tops as forage source (Source: Meyreles *et al.*, 1982).



Increased costs of molasses and decreasing profit margins for intensive beef fattening in developing countries have, in most situations, made high level use of molasses uneconomical. Emphasis is now on using molasses as a vehicle for urea and minerals in the form of liquid mixtures (CIPAV, 1987) or as solidified blocks (Leng and Preston, 1984). The latter technology has proved to be particularly attractive and, following its successful introduction in India (Figure 6.2; Kunju, 1986), it has been transferred successfully to many tropical countries (Leng and Preston, 1984; Sansoucy, 1995).

LIVESTOCK PRODUCTION AND PASTURE

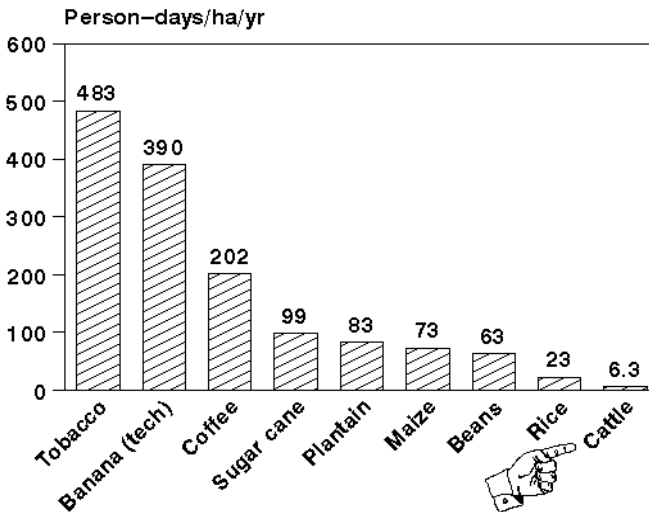
The grazing animal and sustainable use of natural resource

The role of pasture in tropical livestock production is highly debatable. As practised in tropical Central and South America by "ranchers", most of whom are absentee landlords, the system fails on almost all of the sustainability indicators proposed in Chapter 1. On the other hand, the supervised grazing of common land, roadside grasses, and bunds between rice and other food crops, especially in Asia, affords the basis of a living to countless "landless" farmers, especially women. In Africa,

transhumant pastoralism was a life style, that has gradually become less sustainable due to the impact of "development". The upset of the traditional system, and the imbalance caused in the natural wild life, is what has led to the present widespread erosion and desertification.

Supervised grazing has succeeded in Asia because it is highly integrated with crop production which is the dominant activity and there is no conflict. It is a threat in Africa (e.g., the Hado project in Tanzania; Chapter 1), partly because it was the dominant activity and has come under threat by crop farmers; in Africa, grazing is a source of conflict. In Latin America, ranching is also a life style - witness the highly successful (though morally questionable) advertisement for a successful brand of cigarettes. More than any other human activity, in that continent, it has been responsible for immense ecological and social damage (Figure 6.11).

Figure 6.11. Social indicators of sustainability. Extensive cattle ranching in Latin America offers fewest job opportunities of all agricultural activities (Source: Howard-Borjas, 1992).



Pasture can be a sustainable land use system only if it is a by-product of food crop production (the Asian model) or is closely integrated with forestry which should be the dominant activity (agroforestry).

Interestingly, when the Asian model was introduced as the alternative (new) livestock production system in the previously eroded "Hado" region, the results were highly successful and have been sustained (Ogle *et al.*, 1993).

Agroforestry has been practised for many decades in industrial plantations of coconuts, rubber and oil palm, primarily as a means of controlling weed and grass growth (Reynolds, 1988; Sanchez, 1995). The limited technologies introduced consisted of planting aggressive legumes such as tropical kudzu (*Pueraria phaseoloides*), but here the aim was more to aid the tree crop than the animal.

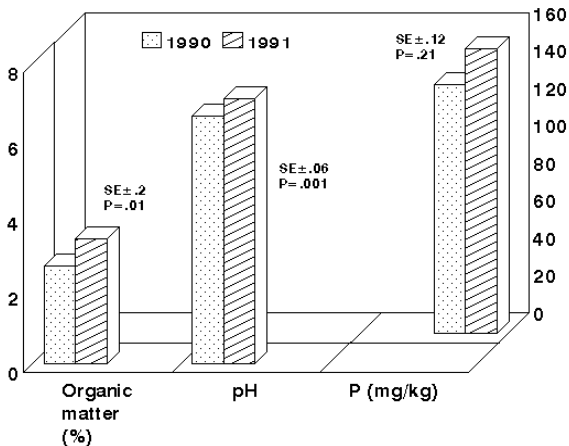
The "Alley farming" system of agroforestry developed in West Africa was never intended for grazing animals but for "cut and carry" management, or simply as a source of mulch and fertilizer (Attah Krah, 1991).

The planting of leguminous trees in association with pasture for sustainable production of animal feed is a new endeavour (Molina, C. and Molina, E. 1994, Personal communication: Rodriguez and Cuellar, 1994). In this system trees such as *Gliricidia sepium*, *Leucaena leucocephala* and *Erythrina fusca* are planted at densities in the range 600 to 1100/ha (*E. fusca*), 10,000 to 20,000 (*G. sepium*, *L. leucocephala*) and 25-50/ha (*Prosopis juliflora*), in association with grasses such as star grass (*Cynodon nlemfuensis*) and Argentina grass (*Cynodon dactylon*). The trees are lopped at intervals of 90-120 days in the case of *E. fusca* and *G. sepium*, browsed at intervals of 40-60 days for *L. leucocephala* or left for the fruits to fall and be consumed in situ or collected (*P. juliflora*). As all of this work is on commercial farms, much of the information is derived from observations and in no cases are there strictly comparable control plots (see Chapter 11 for a discussion of this issue). The use of legume trees and other fodder trees as protein sources for livestock was the subject of a recent FAO Expert Consultation (FAO, 1992).

Some recent data on soil fertility in agro-forestry systems are interesting and extremely relevant to the issue of sustainable use of

natural resources. In the examples, one of a protein bank of *G. sepium* (Figure 6.12) and the other with cattle grazing under *E. fusca* (Figures 6.13, 6.14), soil fertility improved over time or in comparison with similar pastures not associated with trees.

Figure 6.12. Effect on parameters of soil fertility of managing the leguminous tree *Gliricidia sepium* as a protein source for cattle (harvested every 90 days; biomass yield about 80 tonnes fresh foliage/ha/year) (Source: Gomez, M.E., 1992, unpublished data).



The nutritive value of pasture associated with trees

Effects of shade

There is a wealth of literature on the composition of grasses, and how this changes under the influence of management including, cutting, grazing, fertilization, and inter-sowing with herbaceous legumes. There is much less information on the effect of shade on pasture productivity and quality (Sanchez, 1995). Work done in industrial tree crop plantations indicates that increasing degree of shade reduces biomass productivity, increases the content of soluble nitrogenous compounds and decreases that of soluble carbohydrates. These changes are likely to have negative effects on both stocking rate and balance of nutrients.

Figure 6.13. Effect on soil organic matter of managing an association of *Erythrina fusca* (600 or 1100 trees/ha) in association with star grass; trees are lopped at intervals of 90-120 days and leaves fed to housed cattle; star grass is grazed by replacement heifers on a 30 day rotation) (Source: Rodriguez y Cuellar, 1994).

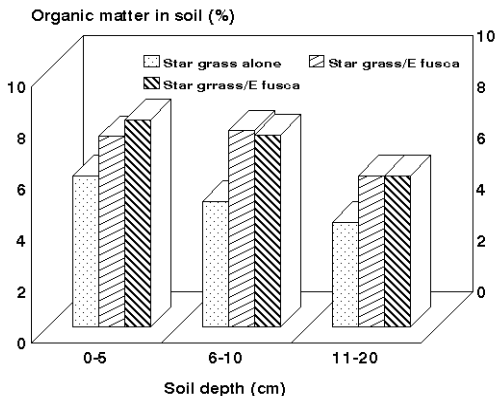
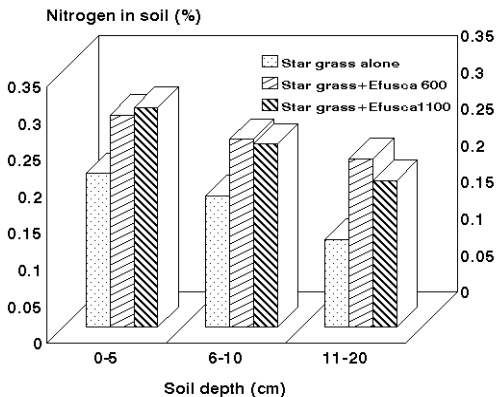


Figure 6.14. Effect on nitrogen (organic) in soil of associating African star grass with *Erythrina edulis* trees planted at 600 or 1100 per ha (Source: Rodriguez and Cuellar, 1994).



There are no comparable data for associations where leguminous tree crops and grasses are managed for animal feed and where shading is cyclical (i.e., zero immediately after lopping increasing over time to almost 100% shade, depending on the tree population and the harvest interval, which is usually between 90 and 120 days).

Supplementation

If the pasture is young (less than 30-40 days regrowth) then in all probability it will contain adequate amounts of fermentable nitrogen, and minerals and little or no "by-pass" protein. It will also (pasture under shade) be deficient in glucose precursors due to low levels of soluble carbohydrates.

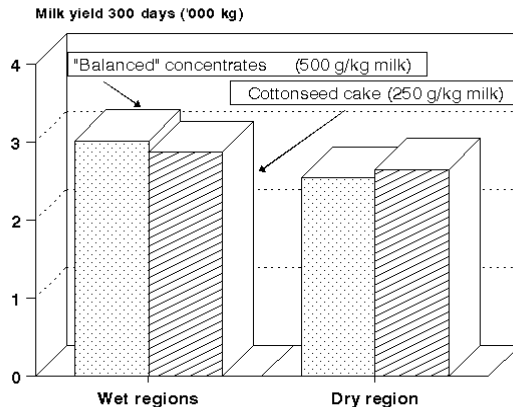
The first priority, in order to increase animal productivity will be the provision of "by-pass" protein. This could be provided by the leaves of the associated trees; otherwise, protein-rich meals from oil or cereal milling should be given. In Mauritius, where dairy cattle are kept in confinement by landless farmers (mostly women), and feed must be harvested from roadsides or sugar cane fields, supplementation with cottonseed meal at only 250g/litre of milk gave the same yield as twice the amount (500 g/litre) of "balanced" concentrates (Figure 6.15).

The second priority will be to increase the supply of glucose precursors. By- product oilseed meals and brans will normally increase the supply of glucose precursors, either via "by-pass" starch or indirectly through increasing rumen propionate.

A more interesting approach, and in line with the strategy of identifying and using truly tropical feed resources, is the use of the crude oil from the African oil palm. "By-pass" oil (protected with calcium salts) is incorporated directly into milk and body fat, thus saving glucose needed for NADPH synthesis when fat is synthesized from acetate (Chapter 5).

This feed resource, which is already being used commercially for feeding to pigs, on several farms in Colombia, promises to have a particular role in complementing tree foliages in the diet of milking cows.

Figure 6.15. A source of "by-pass" protein such as cottonseed cake is a more economical supplement than "balanced" concentrates for milking cows in confinement fed cut-and-carried grass (wet season) and sugar cane tops (dry season) (Source: Boodoo *et al.*, 1990a).



Of special interest is an apparent synergistic effect when the oil is mixed with protein-rich leaves from forage trees which normally are not relished by cattle. The fresh leaves of the tree *Erythrina fusca* are eaten by cattle but not with great relish. Wilting them for 24 hours improved both intake and growth response in crossbred heifers (Cuellar *et al.*, 1992). However, mixing the leaves with 6% palm oil (fresh weight basis) and 2% calcium hydroxide, following wilting, brought about a threefold increase in intake (Rodriguez and Cuellar, 1994). Milk yields and supplement intakes of crossbred Holstein-Zebu cows in three on-farm trials to evaluate the oil/leaves mixture are shown in Table 6.3. Milk production on the mixture of oil and leaves was the same as, or better than, on the control of concentrates (based on oilseed meals and rice polishings).

The optimum amount of any by-pass nutrient-rich supplement for complementing pasture must be determined from a response function curve as was outlined for crop residues above. The data for experiment 3 in Table 6.3 indicate that the optimum amount of oil for the particular

combination of crossbred cows and Star grass pasture was of the order of 350 g daily.

Table 6.3. Mean values for supplement intake and milk production* of F1 cows rotationally grazed on African Star grass and given supplements of fresh foliage of *Erythrina fusca* mixed with palm oil (Source: Cuellar and Rodriguez, 1994).

				SE/Prob
Experiment 1:				
Supplement (kg/d)				
Concentrates	4	2	0	
Foliage/oil	0	4/0.25	8/0.5	
Milk yield (litres/d)	10.4	11.3	11.2	0.16/.001
Experiment 2:				
Supplement (kg/d)				
Concentrates	4	0	0	
Foliage/oil	0	4/0.25	8/0.5	
Milk yield (litres/d)	9.68	9.60	10.2	0.15/0.001
Experiment 3:				
Supplement (kg/d)				
Concentrates	4	0	0	
Foliage/oil	0	4/0.25	5.6/0.35	8/0.5
Milk yield (litres/d)	9.45	8.48	9.23	9.08
				0.17/.001

* Milk yields adjusted by covariance according to yields prior to introducing the experimental supplements