NUTRIENT MANAGEMENT IN TROPICAL FORAGE SYSTEMS - WHAT SHOULD BE, AND WHAT IS PRACTISED

Graeme J. Blair[1] and Peter. Kerridge[2]

[1]Department of Agronomy and Soil Science, University of New England, Armidale, NSW, Australia.

[2] Centro Internacional de Agricultura Tropical, Apartado aéreo 6713, Cali, Colombia

ABSTRACT

The ruminant population in S. E. Asia and tropical America has increased markedly in the last 15 years despite the increasing competition between ruminants and food production in this densely populated region. In most of S.E. Asia forage production is not so much a production enterprise, but an opportunity system utilising forages produced on 'waste' areas and from the crop residues. As cropping intensities increase larger amounts of crop residues are available for ruminants. In the Australian and American tropics, a large proportion of the animal production is under extensive conditions. In all regions, tropical forages are frequently produced on soils of poor nutrient status, often with poor physical conditions. Considerable research on nutrient responses in forages has been conducted in the three regions and farmers are generally well aware of the potential increases in the quantity and quality of feed that can be produced from fertiliser inputs. However, either because of the critical importance of food cropping, low returns to animal production, and or scarce financial resources, fertilisers are rarely applied. The more widespread adoption of available forage germplasm, adapted to the adverse soil and climatic conditions of these areas, appears the best prospect for enhanced forage production. This should be combined with management that ensures efficient cycling of nutrients. Intensive crop-livestock systems offer the best prospect of efficient nutrient management.

KEYWORDS

Nutrients, tropical forages, fertilisers

INTRODUCTION

In this paper, we begin by briefly describing the trends in ruminant production and the feeding systems under which livestock are raised. Brief mention is made of the large body of information available on fertiliser response in order to indicate the type and extent of soil nutrient deficiencies. Then we summarise the results of a brief survey of local agronomists of the actual fertiliser practices used by farmers. Finally, we comment on the future strategy that might best be followed for managing soil nutrient deficiencies.

TRENDS IN LIVESTOCK PRODUCTION IN AUSTRALIA, S.E. ASIA AND TROPICAL AMERICA

Livestock numbers continue to increase throughout S.E. Asia and Tropical America despite the increasing human population density in these regions.

Indonesia, Myanmar and Thailand dominate the large ruminant population in S.E. Asia and Brazil, Colombia and Venezuela in Tropical America (Table 1). In S.E. Asia between 1979/81 and 1994 cattle numbers increased by 55% but buffalo numbers only increased by 6%. The cattle population in Tropical America has increased by 19%, while Australia has recorded a 2% decline over the same period. Approximately, only 50% of the cattle numbers for Australia and tropical America are in tropical regions, the remainder being in temperate or highland areas. However, the large increases in South America have occurred in the expanding tropical frontier areas. The static situation in Central America can be related to civil unrest during this period.

The largest small ruminant population in S. E. Asia occurs in Indonesia and, in tropical America, in Brazil and Mexico. Less than 10% of small ruminants in Australia occur in the tropics. There has been a very significant (59%) increase in small ruminants in S.E. Asia.

Remenyi and McWilliam (1986) predicted that the demand for forage in S.E. Asia and the S. Pacific would double between 1985 and 2000 if there was no change in the typical feed regime and projected trends in ruminant numbers. This doubling in demand was expected to occur despite a projected decline of 33% in meat self-sufficiency. Twelve years after this prediction, and only 3 years away from the turn of the century the demand is on track to reach this prediction. Increasing food production in the regions means an increasing production of crop residues and agro-industrial by-products and, depending on management, this could be used to sustain the increased animal numbers.

In their assessment of the situation in S.E. Asia Remenyi and McWilliam (1986) pointed out that production of forages was not a traditional activity for the majority of smallholders and farmers in the region. Both land and labour constraints were seen as limitations to expansion of forage production. In the intervening years these problems have been exacerbated by increasing human population. Nevertheless, more legumes, grasses and shrubs are being incorporated into existing production systems and are also seen as contributing to maintenance of soil productivity (CIAT 1997).

By contrast in tropical Australia the cattle industry has undergone dramatic change in the last 10 years. Live cattle exports from Northern ports have risen from 49 154 in 1985 to 621 000 in 1995 and are predicted to rise to 700 000 by 2000. Of the 1995 total some 15 000 head were used as breeders in Thailand, Philippines and Indonesia. The live export trade, most of which go to Indonesia and Philippines, has a higher quality demand than the processing trade in the USA which was the main trade in former times and this has resulted in greater attention being paid to both breeding and feeding.

TYPES OF TROPICAL FORAGE SYSTEMS IN USE

South East Asia

Semali (1988) surveyed livestock production systems in Java, Indonesia and found considerable differences between regions in the feeding and forage systems in use (Table 2). In the areas with high human and animal population density cut and carry systems provided the majority of the fodder supply. In areas with high livestock density most of the feed was gathered from land not owned by the livestock raiser. In the areas with lower human population, rice fields provided the majority of the feed supply whilst in areas of high livestock population rice bunds were a major feed supply area. Since this survey crop intensification has increased as human population has increased and would be expected to result in an even greater reliance on crop residues for feed supplies.

Phaikaew, C. (personal communication) has estimated the ownership and feeding systems for large ruminants in Thailand as shown in Table 3. In Malaysia, Wong, C. C. (personal communication) estimates that 90% of the cattle are owned by smallholders and that this, and the inputs into production are unlikely to change in the foreseeable future. "Free" forages from plantations, idle land and along roadsides remain the main sources of feed for animals. Even in the dairy industry in Malaysia half of the producers do not allocate any land for the cultivation of forages and the other half improve only an average of 0.7 ha each.

The plantation segment of agriculture occupies large areas of Malaysia, Thailand, Philippines and Indonesia and integration of grazed pastures with the tree crop offers considerable scope to increase animal productivity in this sector. Twining leguminous covers are usually planted at oil palm or rubber establishment to smother weeds. Shelton and Stür (1991) present data from a number of countries showing the potential animal productivity that can be gained from such systems.

The three strata system developed in Bali, Indonesia by Nitis et al. (1990) based on the type of forage system used by small farmers, offers the potential to increase forage production under intensive conditions and is one of the most innovative forage production systems developed in the region. The grasses and shrub legumes grow on perimeter areas and none of the forage components receive fertiliser additions, but rather rely on re-cycling via crop residues fertilised with dung and urine.

In Vietnam the marked wet and dry seasons, with crop production in the wet season, dictates feeding strategies. Le Viet Ly (personal communication) indicates that in the wet season 80% of feed comes from grazing of natural forages and 20% from crop residues and this situation is reversed in the dry season. As in other S.E. Asian countries dairy cattle are fed on cut forage with some concentrates. Experiments in Vietnam have shown that natural pasture produces only about 1 t DM/ha, but *Pennesetum purpureum* fertilised with 10 t manure/ha can produce 10 t DM/ha and that adding 300 kg N/ha + manure can lift yields to 26 t DM/ha.

In Laos (Horne, P. personal communication) reports that the ruminant population is located mostly in mountainous upland areas when livestock commonly contribute more than 50% to household income in these rural communities (partly because many are so remote and lacking in resources that there is little else they can produce for sale). Commonly animals are sent to graze in the hills and forest in the wet season and return to the rice paddies in the dry. There is very little cut-and-carry supplementation in the barns at present but is likely to become more important in the future. Food production is also likely to become more widespread in marginal upland areas and animal manure, combined with leguminous covers, appears one way to maintain soil fertility.

Tropical America

In contrast to South East Asia, ruminant production is based almost entirely on grazing with little integration of cropping and livestock. Grazing lands account for 75% of the total agricultural land. Nevertheless, there is a great diversity of livestock systems, variation in quality of forage between the grasslands and size of livestock enterprises. Thus, while there are many large beef holdings and dairy farms, there are also large numbers of low income livestock farmers. For example in Brazil, 80% of dairy farms produce less than 100 L/day and account for 40% of the milk produced. In general, there is little use of crop residues. The exception is in the more intensive crop-livestock systems that have been developed recently where pastures may be introduced under a crop and animals graze the new pastures and the crop residue (Vera et al., 1992). In Central America and the Caribbean there are examples of intensive dairy production based on 'cut and carry' fodder of sugarcane or elephant grass and protein banks of the shrub *Leucaena* and herbaceous legume *Arachis pintoi*.

The quality, and hence productivity, of the natural grasslands is quite variable. In the coastal areas and the Andean and Central American hillsides (to 2000 m altitude) with soils of medium fertility receiving >1200 mm rainfall and heavily grazed, the grass vegetation is frequently dominated by native species of *Paspalum notatum*, *Paspalum conjugatum* and *Axonopus compressus* on which beef production, of the order of 90 kg/hd and 60 kg/ha/annum, is achieved without fertiliser input. Where there is a prolonged dry season, elephant grass and sugar cane are used as fodder supplements for dual purpose dairy/beef systems.

In contrast, in the vast savanna areas of Brazil, Bolivia, Colombia and Venezuela, the natural grasslands have much lower productivity due to the low feed value of the native grasses growing on highly weathered soils of low pH (4.2) and base status (< 1 meq/100g). Beef productivity is of the order of 50-60 kg/hd and 12-15 kg/ha/annum. Introduction of improved grasses adapted to the these acid infertile soils, together with small inputs of P (20 kg/ha) and other nutrients lifts productivity to 120 kg/hd and 200 kg/ha (Lascano, 1991). The percentage of the area with improved grasses varies from 20% of the farm area in Colombia to 60% in Brazil. It has been demonstrated that introduction of legumes, in particular *Arachis pintoi*, can lift their productivity about two-fold and increase the sustainability of the system, but there has been little adoption to the present.

There is also significant cattle production in the cleared margins of rainforest areas where cattle have been introduced largely as a means to obtain title to land or to capitalize on land value through sales to other land owners. Improved grasses were sown but many areas have reverted to secondary forest or unproductive grassland because of poor adaptation of introduced grasses, e.g. *Panicum maximun*, nutrient depletion and poor management. Productive and sustainable grasses and grass-legume associations are now available for these areas but their adoption will necessitate a higher level of management than exists at present.

Australia

Tropical ruminant production systems in Australia can be broadly divided into two segments. Beef breeding enterprises are generally located in the drier inland areas and production fluctuates wildly depending on seasonal conditions. Large fluctuations in rainfall, and variations in beef prices means that little pasture improvement and fertiliser use is undertaken. Improvements that have taken place rely mainly on Stylo pastures fertilised with low (<10 kg P/ha) applications of single superphosphate. Animal supplementation with P has become common, and in recent years early weaning and supplementation with molasses and urea has increased. Whilst this has allowed animals to be retained on-farm during drought periods it has lead to severe rangeland degradation in some areas.

On the wet tropical coast of Queensland nitrogen fertilised grass is the major fodder source used. Para grass, grown in areas of ponded water collected during the wet season, also contributes significantly to feed resources in some coastal areas. The other segment is the intensive dairy industry which is based on heavily fertilised N grass pastures and concentrates.

NUTRIENT NEEDS OF FORAGE SYSTEMS

South East Asia

The soils of S.E. Asia are mostly highly weathered utisols and oxisols with only small areas of fertile alluvial or volcanic soils. Dent (1980) estimated that 59% of the soils of the area limited production through nutrient deficiency. This, together with the high demand for good land for food crop production, means that the land available for specialist forage production is both limited and poor. In Indonesia, fertiliser responses in forages have been recorded in many areas, as have responses in food crops. In experiments on a Glossudalf soil in S. Sulawesi Blair et al. (1978) recorded responses to S in *Centrosoma pubescence* on a soil previously fertilised with triple superphosphate. These plot responses to S were repeated in an experiment grazed by cattle (Hunt et al., 1991) where liveweight gain was increased from 69.5 to 158.2 kg/ha/yr through addition of S.

Much research on forage responses to fertilisers has been conducted in Thailand over a number of years. In the Khon Kaen Pasture Improvement Project (KKPIP) conducted in N.E. Thailand substantial responses to P, S and K fertiliser application in Stylo were recorded at many locations. Aitken (1979) reported responses to S on 10 of 13 soils from the North-east. Wilaipon and Wilaipon (1982) reported higher yields from *Stylosanthes humiles* (CPI 61674) than from *S. hamata* cv Verano at all P and S levels. Because of the low pH and sandy nature of most N.E. soils, the use of native phosphate rocks and gypsum of differing particle size as alternatives to highly water soluble P and S sources was investigated. Aitken et al. (1980b) showed marked differences in effectiveness between rock sources and in another study Aitken et al. (1980a) showed that gypsum of 1-2 or 2-5 mm particle size was required to retain sufficient S in the topsoil throughout the season for forage growth.

Potassium deficiency was found to be widespread throughout N.E. Thailand with responses to K recorded on 50% of the upland soil types of the area (Topark-Ngarm and Aitken, 1982).

In Malaysia there is much experimental evidence to indicate the need of proper fertilisation for efficient forage production (eg Tham and Kerridge, 1982) but planted grass and fodder cannot compete with other feed sources if the opportunity cost of land is included. The most deficient nutrient for legume growth is P, followed by K, Mo and Cu. S deficiency is not common due to high S accretion in rainfall (Zahari et al., 1983). In beef, sheep and goat production, many farmers do not allocate any land for grass cultivation and hence there is no adoption of fertiliser recommendations. Ruminants are raised in mixed farming systems depending largely on roadside grazing and grasses growing on idle and/or marginal land or access to plantation areas. The feasibility of rearing these animals is therefore highly dependent on the access to such grazing areas and continuing labour to look after them.

In Laos, the main soil nutrient limiting forage productivity is P. In large areas of Xieng Khouang province, for example, bicarb P levels are commonly <5ppm with pH_w commonly <5. Some research in Xieng Khouang has shown that without the addition of P at establishment, even the most robust forages do not survive. The Forages for Smallholder Project has recently conducted a trial with >100 forage species and 5 rates of P on the poor soils and found marked differences in response between species. In general, the soils are not strongly P adsorbing and as a result, 20 kg of P/ha appears to have given more that 80% of the response (although with considerable variation between species). Some Stylos grew well without P addition.

Tropical America

The soils in the savannas and a large portion of the hillsides are very acid (pH 4.2-5.5) with low exchangeable P and extractable bases. Nevertheless, soils of higher pH (5.5-6.5) and fertility do occur along the Pacific coast and in some hillside regions. However, as there is little commercial fertiliser usage both native and introduced species that are well adapted to low fertility are used. Numerous fertiliser experiments have been carried out but the emphasis in nutrient management has been to select species that are well adapted to acid infertile soils (Rao et al., 1993).

Fodder grasses. Fertiliser rate experiments with N have shown linear responses up to 300 kg/ha N however, fodder grasses are also being selected for low or minimal N input (Xavier and Boddey, 1995).

Pure grass pastures. Responses are greater during establishment and a minimum of 10-20 kg/ha P is recommended. In many cases P is supplied as rock phosphate. Improved pure grass pastures have now remained productive for 20 years at Carimagua on the eastern plains of Colombia, with a total input of 80 kg/ha P and lenient management (Lascano and Estrada, 1989). There is increasing evidence from Brazil that associative N fixation by endophytic bacteria may be responsible for maintenance of grass productivity without N application in semi-intensive situations provided that nutrient deficiencies, in particular P and Mo, are corrected (Boddey and Victoria, 1986; Miranda et al., 1990). There appear to be differences in ability to maintain productivity without N input between species and accessions and between sites suggesting that some ‘inoculation’ may be necessary.

Grass-legume associations. Though not widely adopted, legumes have persisted in association with grasses in many experimental and farm situations for from 10 to 20 years. The key appears to be maintenance of nutrients (the requirement being greater for legumes than grasses) persistence through stoloniferous habit or high seed production and appropriate management. Grazing management needs to be lenient in the case of spreading legumes such as *Pueraria phaseoloides* (Lascano, 1991) or heavy for stoloniferous legumes as *A. pinoti* (Lascano, 1991). On the savanna soils, nutrient responses have been obtained to P, Ca, K, Mg, and S during establishment and as maintenance applications, the degree of requirement and degree of response being related to both soil type and species (e.g. Salinas et al., 1990). There is a lower requirement on the light textured soils for P but a higher requirement for K. *Centrosema acutifolium* is better adapted to acid infertile soils than *C. pubescens*. A minimum recommendation for successful establishment of legumes is (kg/ha) P20, Ca100, K20, S10, Mg10 (CIAT, 1987).

Mo deficiency is likely to become more widely recognized as forage legumes become more widely adopted (Johansen et al., 1997). Experience suggests that it is not feasible to maintain legumes under conditions of minimal input of nutrients and management. Legumes are most likely to be adopted and well managed in more intensive situations such as integrated crop-livestock systems and for dairy production, than in extensive beef production.

Australia

In many areas of tropical Australia, where introduction of tropical legumes and grasses could benefit livestock production and profitability, the soil levels of P and S are low. Results and conclusions from collaborative research aimed at overcoming the gross P deficiency for both pasture and animal in northern Australia was presented in a series of papers published in Tropical Grasslands Vol 24 (1990). Recommendations were given for various regions and extensive and intensive systems. The use of legumes to increase protein supply in the dry season was recommended for all areas with direct P supplementation to animals when bicarbonate P was <4-5 ppm. It was suggested that soils with >10 ppm P be selected for intensive systems (using legumes other than stylos), except in Central and Southern Queensland where use of P fertiliser could be economic (Miller et al., 1990). Thus recommendations for use of fertiliser was limited to some intensive systems, the stylos being able to grow without fertilisation at soil P levels <4-5 ppm. This strategy has now been widely adopted.

In this part of the world cattle stocking rates are low, the economics of beef production variable and rainfall unpredictable. Research at the Lansdowne site over a 4 year period showed that cattle liveweight gain responded to fertiliser P applied to the native grass pasture, and that there was an additional response to P in the drinking water (Winter et al., 1990).

In order to reduce the cost of introducing species into native grasslands band or strip sowing has been advocated. Miller et al. (1993) points out that such a practice requires careful grazing management as cattle are attracted to the fertilised areas (Jones and Betteridge, 1994) which can result in over-grazing and loss of the sown species.

In a study of cattle productivity on *Panicum maximum var trichoglume* cv Petrie and *Chloris gayana* cv Pioneer pastures growing on initially fertile brigalow soils in S.E. Queensland Jones et al. (1995) found that pasture run-down could be alleviated over 20 years by using low stocking rates. At higher stocking rates N fertiliser was required to maintain the system. Crude economic analysis of this trial indicates that $100/ha/yr would be spent on N fertiliser (100 kg/ha x $1/kg N) to produce additional beef worth $85 (85 kg/ha/yr additional liveweight x $1/kg liveweight). In addition to these unfavourable economics, reduction in stocking rate and destocking may be necessary at critical times to maintain green panic as the desirable dominant species.

In summarising the P research in beef cattle production in Tropical Australia, Winter et al. (1990) points a gloomy picture and indicates that “the P story in beef cattle production is far from clear”. He indicates that in grossly deficient situations, where phosphorasis occurs, economic responses to P application in growth and reproduction rate will occur. In marginally deficient situations responses are uncertain because of difficulties in establishing the marginal deficiency and in measuring small responses in such a variable environment.

Increasing profitability in dairy production in Australia has lead to renewed interest in pasture fertilisation in tropical Australia. Minson et al. (1993) indicate that although the tropical grasses are capable of yielding 50 t DM/ha/yr they rarely produce 17 t DM/ha/yr and are high in fibre and low in protein content which restricts milk production. In addition the twining legumes, which were selected for extensively grazed systems, are too unstable to be used in commercial situations. Thus increasing interest has been directed to species more suited to heavy grazing such as *Arachis pintoi* cv Amarillo, *Lotus pedunculatus* cv Maku and browse shrubs such as *Leucanena leucocephala.* All these species require fertiliser inputs to maintain productivity and careful fertiliser and grazing management to retain them in swards with tropical grasses.

Because of the management difficulties associated with forage legumes in grass swards increasing attention has been redirected to N fertilised grass pastures for dairy cattle. Cowan et al. (1995) studied the effect of N fertiliser on *Chloris gayana* cv Callide stocked at 2 Holstein-Friesian cows/ha and recorded a milk yield response of 8 kg milk/kg N applied up to 150 kg N/ha/yr. In addition, conception rates increased from 58 to 92% from 0 to 600 kg N/ha/yr. The results indicate a maximum margin over feed costs at 334 kg N/ha/yr over the total grazed area.

CONSTRAINTS FACED BY FARMERS TO EFFICIENT NUTRIENT MANAGEMENT

S.E. Asia

The tree plantation areas of Thailand, Malaysia, the Philippines and Indonesia offer potential for the expansion of livestock production but development in these areas has been slow.

Sophansdora and Tudori (1990) indicate that in Thailand the type of pasture used and the attitude of farmers to pasture improvement under plantation crops are major constraints to development. Similar constraints to livestock development, as mentioned above, were identified in N. Sulawesi, Indonesia by Sandolkh and Kaligis (1990).

For Malaysia, Tajuddin et al. (1991) indicate that income potential from sheep rearing under rubber was unattractive under the management strategies in place at that time. Given the poor nutrient status of the soils under both rubber and oil palm, fertiliser addition, particularly P, will be required and it is doubtful if smallholder producers will divert scarce fertiliser resources from the main tree crop to the animal sideline. However, in plantation crops, the pasture will obtain some benefit from the fertiliser applied to the trees and in return, where there is legume-grass pasture, should contribute to N fixation and nutrient cycling.

Much research has been conducted in the Philippines on forage evaluation and fertiliser management. Arganosa and Bato (1992) reported that despite this considerable research effort that “To date, however, technologies generated towards the improvement of nutrition and physiology of ruminants are not well adopted by farmers.“ Most current ruminant production in the Philippines comes from ruminants fed on vegetation from open grasslands and forested areas, agro-industrial by-products, crop residues and weeds from unused lands, consequently no fertilisers are used. Moog and Faylon (1991) state that agrarian reform in the Philippines is likely to give landholders more incentive to more efficiently produce and utilize biomass through the integration of forages and livestock under coconuts. However, agrarian reform has been slow and cattle and buffalo numbers declined in the Philippines between 1979-81 and 1994. This has meant that little forage development has taken place. The large importation of live cattle into the Philippines for feedlotting has however created small pockets of intensive forage production in the vicinity of these facilities.

Little forage fertilisation is practiced in Indonesia despite the large amount of research which has shown substantial responses to fertiliser application. Feedlotting, particularly of imported cattle, is increasing and has led to some specialised forage producing from fertilised areas.

Phaikaew, C (personal communication) indicates that although some Thai dairy farmers apply N after each cut of *Barcharia ruzizienses* and *Panicum maximum* the practise is not widespread. Phaikaew lists unreliable rainfall, the long dry period, decreasing area of communal land, limited forage varieties, lack of pasture production management and know-how, low soil fertility and expensive fertilisers as the primary constraints to increase animal production from forage based systems. In selected areas, where there is a high cash flow from milk sales, or cattle fattening, N application, in conjunction with return of manure is practiced.

In Malaysia the high fertiliser cost is a major barrier to the adoption of fertiliser input for efficient livestock production. Unless the farmers are entrepreneurs opportunities to improve nutrient management will be limited to cultivated grasses and legumes for leaf meal production either for the ruminant or the equine industry. The opportunity and challenge to explore the roughage component of the horse feed industry in Malaysia is vast, particularly in the area of efficient nutrient management of optimal production.

In Vietnam, as in other S. E. Asian countries, lack of cash and uncertain rainfall are the major constraints to the use of fertilisers on forages. Labour is plentiful but this is directed towards food crop production. In the short term, fertilisers are only likely to be used for milk production where the farmer can obtain a daily return from his investment.

The situation in Laos is similar to other developing SE Asian countries. Most Lao farmers are desperately poor and application of fertilisers, particularly P, to forages is not feasible. Rock phosphate reserves exist in Laos but these are undeveloped. Severe P deficiency in animals is common in these areas and although supplementation with bone meal or fertiliser P solves the problem quickly, it is not practiced (Gibson, 1997). In shifting cultivation areas, farmers keep livestock for the very reason that they don’t need management. So, lack of resources (especially cash and labour) are very strong limitations to any improvement in management of nutrient resources.

Shelton et al. (1985) reported the results of a survey of Australian and overseas forage scientists on pasture development and production in S.E. Asia. The results indicated little adoption of improved pasture technology by smallholders. A unanimous conclusion from the survey was that the nutrient status of soils that can be used for forage production in developing countries requires more attention. Most respondents felt that lack of analytical services, insufficient experimental data and unfavourable economic circumstances prevent adoption of available technology. Choice of species to suit the soil fertility conditions was seen as the most acceptable first step in improving productivity. A collaborative project between seven countries in the region, Forages for Smallholders, using farmer participation, is now achieving successful adoption of improved forages in a variety of situations. However, any nutrient input is limited because of associated cropping.

Tropical America

A survey among forage agronomists working with farmers has highlighted various practices and constraints to improved nutrient use:

i) because species are well adapted to infertile soils, e.g. the brachiarias, there is no need for much fertiliser addition,

ii) there is a lack of knowledge or information on the advantages from application of fertiliser to pastures, whereas it is accepted with fodders i.e. forages grown for ‘cut and carry’,

iii) little attention has been directed to developing efficient nutrient management strategies at the farm level,

iv) high cost of fertilisers relative to return from animal products and the lack of demonstration of economic benefit through benefit-cost analyses,

v) little information is available to farmers on the use of legumes whose adoption might contribute to improved nutrient management,

vi) there is a lack of integrated crop-livestock systems.

In summary, it was considered that improved nutrient management should also be approached from the viewpoints of use of grasses and legumes adapted to low nutrient conditions, increased use of legumes and the development of integrated livestock systems, in addition to fertiliser use. On average, only 5% of livestock farmers use fertilisers at present and these were largely also crop farmers. Thus as crop farmers were more likely to consider nutrient use than those who only keep animals, integrated crop-livestock systems should be encouraged. These reasons have considerable similarity to the constraints mentioned for South East Asia even though the farming systems are quite different.

Australia

Whilst the very considerable research effort in Tropical Australia has demonstrated substantial pasture responses to fertiliser addition, where climatic conditions are favourable, the technology has not been widely adopted because of a series of unfavourable rainfall years and large fluctuations in beef cattle prices.

In a survey of producers in two areas of Queensland conducted by Wilson et al. (1990) the respondents indicated a lack of investment in fertilisers. Most were well aware of the benefits of fertiliser use but the profitability of beef production limited its use.

Mears and Partridge (1985) found that the total area of pasture fertilised in coastal Queensland and New South Wales reached 390,000 ha in 1974 but dropped 50% in 1974/75 following a beef price slump. They also indicated that the area of effective improved pasture was only 1.5.% of potential sown pasture in coastal Queensland. Cowlrick, T. (personal communication), from Incitec Fertilisers, Brisbane, estimates that the current fertiliser use on Stylo based pastures north of the Tropic of Capricorn amounts to only a maximum of 3000t/yr, mainly as single superphosphate. On the wet tropical coast of Queensland fertiliser usage is estimated at 9000t/yr, mainly as urea. This low usage of fertiliser reflects the current state of the beef industry with coastal finishing being more profitable than dryland breeding.

Because of the great uncertainty in the beef producing areas of Australia, Mears and Partridge (1985) indicate that increased emphasis needs to be placed in selection of the most adapted genotypes for particular areas rather than broad regional adaptation. The adapted species are more likely to be able to withstand the variable grazing pressures and stop/start fertiliser additions characteristic of the region.

It is likely that any future expansion of the Northern beef herd in Australia will take place on the wet coast of Queensland, areas with higher and more reliable rainfall of the Gulf of Carpentaria and in association with the Ord River Irrigation scheme in the Northern Territory. The live cattle trade to S. E. Asia is likely to be the most lucrative outlet for these cattle and this is likely to result in increased fertiliser use.

ALTERNATIVES TO CORRECTION OF NUTRIENT DEFICIENCIES BY FERTILISATION

It is now obvious that farmers in developing country situations or under extensive production systems will use minimal amounts of fertiliser as inputs to these systems. However, there are several alternatives to high fertiliser inputs to ensure reasonable forage (and animal) production on infertile soils:

i) use forage germplasm that is well adapted to infertile soils,

ii) ensure that nutrients that are in the system or added as fertilisers are used efficiently,

iii) develop integrated crop-forage systems in which the forage benefits from residual fertiliser applied to the crop and the crop from the enhanced chemical an physical characteristics following a forage ley,

iv) to directly supplement animals with essential minerals,

v) a combination of the above.

i) Adapted germplasm. Early research by Andrew and Norris (1961) demonstrated that the genus Stylosanthes was well adapted to low P soils. This led to focus on the genus for use in low P situations and has resulted in *S. scabra* and *S. hamata* being sown over a million hectares in northern Australia. Similarly, the recognition of the good adaptation of Brachiaria decumbens cv Basilisk to acid infertile soils of the savannas of tropical America has resulted in 35 Mha being sown in Brazil alone (Vera et al., 1992). Subsequent research on adaptation of forages to infertile soils and subsequent field evaluation in Australia, tropical America and S. E. Asia has resulted in a sound knowledge of adaptation of grass and legume germplasm to different soil and climatic niches (e.g. Andrew and Kamprath, 1978; Rao et. al., 1993; Stür et al., 1995).

There is still considerable scope to identify superior accessions among wild forage germplasm. The success of the genus Brachiaria in tropical America, led to intensive collection of new germplasm from Africa in the 1984-1986 period.

Subsequent evaluation has identified accessions with superior characteristics than the widely grown cultivar Basilisk (Miles et al., 1996). The production gains that can be achieved from selection of elite germplasm under low soil fertility conditions can be seen in the Gliricidia experiment of Sukanten et al. (1995) in Indonesia. They recorded a 65% range in fodder yields and a 110% range in wood yields among the 16 provenances tested. A better understanding of the mechanisms behind good adaptation will further facilitate selection and provide a basis for genetic manipulation.

The advantage of selecting forage genotypes for specific situations can be seen in the data of Lowe et al. (1991). In their experiment with unsupplemented Holstein-Friesian cows, changing from *Digitaria eriantha* subsp pentzii (Pangola grass) to an elite selection of *Digitaria milanjiana* based on improved leaf digestibility, resulted in increases of 5.8% in milk production 13% in butterfat and 10.9% in protein. This additional production required no additional fertiliser input.

Where forages are grown in conjunction with intensive crop systems or under reasonable levels of fertilisation then high quality forages should be used. Where they are grown under adverse soil conditions, well adopted forages should be selected and used.

ii) Efficient use of nutrients. Efficient use and cycling of nutrients is critical to maintenance of productivity where there is no, or minimal input of nutrients. Fisher et al. (1997) have reviewed nutrient cycling in tropical pastures under the acid infertile savannas of tropical America. They provide explanations or suggest hypotheses as to why productivity has been maintained in pure grass pastures for up to 30 years with no or little input of nutrients. They consider that the main reasons are internal cycling, microbial cycling, supply from primary sources, limiting stress on the pasture system, minimisation of losses and associative N fixation. Efficiency is considerably improved by associated legumes which contribute N, which in turn results in increased macro- and micro-faunal activity and more rapid turnover of nutrients such as P.

Removal and transfer of nutrients can also be critical in maintaining productivity. Nitrogen can be readily be leached from pure legume stands at the commencement of the wet season. There are high losses through transfer in fodder or ‘cut and carry systems. Considerable emphasis is given in the literature to the importance of the return of manure to the farm but little research has been devoted to minimising losses during collection and storage of dung and urine.

Use of deep rooted plants such as shrubs and trees will help retain and re-cycle nutrients.

iii) Integrated crop-livestock systems. There are large benefits to be obtained from integrated crop-livestock systems in N input, nutrient cycling, improved physical structure and disease control in addition to lower risk through increased diversification. In tropical America it has been shown that pasture establishment costs can be lowered through the use of a ‘nurse’ cereal crop (Vera et al., 1992). Establishment is more rapid and productivity maintained over the longer term due to the residual nutrients supplied to the crop.

Likewise in the intensive farming systems of S.E. Asia, there can be synergy in use of nutrients where forages are incorporated in traditional forage systems. In Bali, farmers are now growing Napier grass on rice bunds and incorporating Leucanea and Gliricidia in boundary lines and home gardens. This has allowed them increase cash income from fattening 2-4 cattle a year without forgoing crop yield. Presumably nutrients are being recycled in the farm through manure and irrigation water (Rika, I.K. personal communication). In Kalimantan, farmers are incorporating legumes as living mulches into upland farming systems and deriving benefit from N input and presumably disease control (Tuhulele, 1997).

iv) Supplementation of animals. This can be considered as efficient use of scarce nutrients. It is practiced widely in tropical Australia (Winks, 1990) and tropical America (Lascano, 1991) and could be more widely used in S.E. Asia when farmers realize the benefits (Gibson, 1997).

CONCLUSIONS

There is a minimal amount of fertilisers applied to forage crops except in intensive production systems such as milk production and cattle fattening. This is likely to continue, hence attention must be focussed on management of nutrients rather than application of nutrients. Thus renewed research effort should be devoted to the selection and adoption of nutrient efficient germplasm. Both selection and adoption will best be achieved with farmer participation and not through traditional experiment station and top-down extension methods. Attention also needs to be given to ensuring that the nutrients in the system are cycled efficiently.

Despite the already intensive production systems, there is likely to be increased intensification, particularly in upland or non-irrigated areas. Just as livestock density is greatest in intensive irrigated areas then it is likely to become so in intensive upland systems. Increasing living standards will increase the demand for animal products and in the case of S.E. Asia will lift demand for more intensive livestock systems in milk production and fattening of large and small ruminants away from animals for draft. This will increase the demand for improved forages and justify some inputs, such as fertilisers. In tropical America there is a huge scope for development of integrated crop-livestock systems which will both justify the input of nutrients and increase the efficiency with which they are retained and utilized in the farming system.

Attention needs to be focussed on integrating crop and livestock research so that resources are used effectively and not to only promote one endeavour. Such research should focus on creating more sustainable production systems in upland or non-irrigated areas incorporating improved grasses and legume and shrubs in the system in such a manner as to optimize nutrient use.

Given the increasing population in S.E. Asia and Tropical America, and the general increase in the standard of living in these regions the ruminant population will continue to increase. As crop production intensifies to feed the increasing population crop residues, either direct or processed will increasingly be used as the basal forage resources. Competition between food crops and animals will probably result in more intensive animal production systems.

Despite the large amount of quality research on nutrient responses on forages throughout the 3 regions covered in this paper little forage fertilisation is practiced except in relatively high intensity industries such as with production and cattle feedlotting.

There has been a large research investment in germplasm selection for adverse soil conditions but much of this material has not reached animal raisers. More effort is required to find suitable plant/soil/animal/climate matches for this germplasm. In smallholder systems which dominate in S. E. Asia genotypes which supplement the generally poor quality crop residues that can be grown with little or no minimal fertiliser inputs and can stand periodical mis-management are required.

Any system that does not return some nutrient to the landscape is a form of mining and will not be sustainable in the longer term. It is imperative to continue to develop crop-livestock systems that are sustainable. The best prospect lies in intensifying the more productive and resilient areas and promoting re-afforestation of the more fragile areas. Intensive production systems must also become commercial and provide income for input of nutrients.

In the longer time slow release fertilisers with a high residual value are required to replace the nutrient removed in the forage.

ACKNOWLEDGMENTS

We wish to acknowledge the cooperation of the following people who provided relevant information regarding their respective countries. C.C. Wong, Malaysia; C. Phaikaew, Thailand; Le Viet Ly, Vietnam; P. Horne, Laos; T. Cowlrick, Australia and I.K. Rika, Indonesia.

REFERENCES

Aitken, R.L. 1979. Soil analysis for predicting sulphur responses in pasture soils from Northeast Thailand. Pages 72-78 *in* Khon Kaen University Pasture Improvement Project Annual Report 1979.

Aitken R.L., J.D. Hughes, N., Wilaipan, and P. Hengtrakal. 1980a. The effect of particle size of added gypsum on sulphate leaching in two upland soils. Pages 56-58 *in* Khon Kaen University Pasture Improvement Project Annual Report 1980.

Aitken R.L., B. Topark-Ngarm, J.D. Hughes, and S. Soonthansorn. 1980b. An evaluation of some Thailand rock phosphates as phosphorus fertilisers on pasture soils. Pages 50-53 *in* Khon Kaen University Pasture Improvement Project Annual Report 1980.

Andrew, C.S. and E.J. Kamprath. (eds). 1978. Mineral nutrition of legumes in tropical and subtropical soils. CSIRO, Melbourne. pp 414.

Andrew, C.S. and D.O. Norris. 1961. Comparative responses to calcium of five tropical and four temperate pasture legume species. Aust. J. Agric. Res. **12:** 40-55.

Arganosa, A.S and R.V. Bato. 1992. Utilization of feed resources in relation to nutrition and physiology of ruminants in the Philippines. Proc. 25th Int. Symp. of Trop. Agric. Res. Tsukuba, Japan, September 24-25, 1991. Trop. Agric. Res. Ser. No. 25 pp. 46-55.

Blair, G.J., P. Pualillin, and S. Samosir. 1978. Effect of fertilizers on the yield and botanical composition of pastures in South Sulawesi, Indonesia. Agron. J. **70:** 559-562.

Boddey, R.M. and R.L. Victoria. 1986. Estimation of biological nitrogen fixation associated with *Brachiaria* and *Paspalum* grasses using ^{15}N labelled organic matter and fertilizer. Pl. Soil **90:** 265-292.

CIAT. 1987. Annual Report.

CIAT. 1997. Report of annual meeting of the Forage for Smallholders Project. Hainan, January 1997. CIAT Working Paper. CIAT, Cali, Colombia.

Cowan, R.T., K.F. Lowe, W. Ehrlich, P.C. Upton and T.M. Bowdler. 1995. Nitrogen-fertilised grass in a subtropical dairy system. 2. Effect of level of nitrogen fertiliser on animal production. Aust. J. Exp. Agric. **35:** 137-143.

Dent, F.J. 1980. Major production systems and soil related constraints in South-East Asia. Pages 79-106 *in* Priorities for Alleviating Soil Related Constraints to Food Production in the Tropics. IRRI Los Baños, Philippines.

FAO. 1997 FAOSTAT database results, web site: http://apps.fao.org´k.Stocks & Domain.

Fisher, M.J., I.M. Rao and R.J. Thomas. 1997. Nutrient cycling in tropical pastures, with special reference to the neotropical savannas. Int. Grass, Cong. Canada 1997. pp. 371-382.

Gibson, T. 1997. The Plain of Jars: an example of phosphorus deficiency for forages and livestock. SEAFRAD Newsletter: Issue 4. pp2-3.

Hunt, M., A.R. Till, G.J. Blair, D. Bulo and P. Orchard. 1991. Studies on native and improved native pastures in South Sulawesi, Indonesia-Effects of sulfur fertilizer and stocking rate on animal production. Asian-Australasian J. Anim. Sci. **4:** 255-262.

Johansen, C., P.C. Kerridge and A. Sultana. 1997. Responses of forage legumes and grasses to Molybdenum. Pages 202-228 *in* U.C. Gupta ed. Molybdenum in Agriculture. Cambridge University Press.

Jones, R.J. and K. Betteridge. 1994. Effect of superphosphate, or its component elements (phosphorus, sulfur and calcium), on the grazing preference of steers on a tropical grass legume pasture grown on a low phosphorus soil. Aust. J. Exp. Agric. **34:** 349-353.

Jones, R.M., C.K. McDonald and M.W. Silvey. 1995. Permanent pastures on a brigalow soil: the effect of nitrogen fertiliser and stocking rate on pastures and liveweight gain. Trop. Grass. **29:** 193-209.

Lascano, C.E. 1991. Managing the grazing resource for animal production in the savannas of tropical America. Trop. Grass. **25:** 66-72.

Lascano, C.E. and J. Estrada. 1989. Long-term productivity of legume-based and pure grass pastures in the Eastern Plains of Colombia. Proc. XVI Int. Grass. Cong. Nice, France. pp 1179-1180.

Lowe, K.F., R.J. Moss, R.T. Cowan D.J. Minson and J.B. Hacker. 1991. Selecting for nutritive value in *Digitaria milanjiana*. 4. Milk production from an elite genotype compared with *Digitaria eriantha* ssp. *pentzii* (pangola grass). Aust. J. Exp. Agric. **31:** 603-608.

Mears, P.T. and I.J. Partridge. 1985. Commercial usage of improved pastures in the Australian sub-tropics. Proc. 3rd Aust. Conf. on Tropical Pasture pp 119-127.

Miles, J.W., B.L. Maass and C.B. do Valle (eds). 1996. Brachiaria: Biology, Agronomy and Improvement. CIAT, Cali, Colombia. pp.288

Miller, C.P., J.A. Taylor and M.F. Quirk. 1993. Tropical pasture establishment. 8. Management of establishing pastures. Trop. Grass. **27:** 344-348.

Miller, C.P., W.H. Winter, D. B. Coates and P.C. Kerridge. 1990. Phosphorus and beef production in northern Australia. 10. Strategies for phosphorus use. Trop. Grass. **24:** 239-249

Minson, D.J., T. Cowan and E. Havilah. 1993. Northern dairy feedbase 2001. 1. Summer pasture and crops. Trop. Grass. **27**: 131-149.

Miranda, C.H.B., S. Urquiaga and R. M. Boddey. 1990. Selection of ecotypes of *Panicum maximum* for associated biological nitrogen fixation using the ^{15}N isotope dilution technique. Soil Biol. Biochem. **22:** 657-663.

Moog, F.A. and P.S. Faylon. 1991. Integrated forage - livestock systems under coconuts in the Philippines. Pages 144-146 *in* H.M. Shelton and W.W. Stür eds. Forages for plantation crops. Proc. of Workshop, ACIAR Proc. 32 Australian Centre for International Agricultural Research, Canberra, Australia.

Nitis, I.M., K. Lana, M. Suarna, W. Sukanten and S. Putra. 1990. Three strata forage system for smallholder in dryland farming area. Indonesian Agric. Res. Dev. J. **12:** 23-28.

Rao, I .M., R.S. Zeigler, R. Vera and S. Sarkarung. 1993. Selection and breeding for acid-soil tolerance in crops: upland rice and tropical forages as case studies. BioSc. **43:** 454-465.

Remenyi, J.V. and J.R. McWilliam. 1986. Ruminant production trends in Southeast Asia and the South Pacific. Pages 1-6 *in* G.J. Blair, D.A. Ivory and T.R. Evans eds. Forages in Southeast Asian and the South Pacific Agriculture. Proc. of Int. Workshop. ACIAR Proc. 12 Australian Centre for International Agricultural Research, Canberra, Australia.

Salinas, J.G., P.C. Kerridge and R.M. Schunke. 1990. Mineral Nutrition of Centrosema. Pages 119-150 *in* R. Schultze-Kraft and R.J. Clements (eds) Centrosema: biology, agronomy, and utilization. CIAT, Cali, Colombia.

Sandolkh, I.W. and D.A. Kaligis. 1990. Prospects for integration of forages for ruminants into coconut plantations in North Sulawesi. Pages 140-143 *in* Khon Kaen University Pasture Improvement Project Annual Report 1990.

Semali, A. 1988. Multivariate Classification of Java into Agro-Ecosystems and the Constraints to Annual Productivity Imposed by Forage Availability. M.Rur.Sci. Thesis. The University of New England Armidale, N.S.W., Australia.

Shelton, H.M. and W.W. Stür. 1991 Opportunities for integration of ruminants in plantation crops of Southeast Asia and the Pacific. Pages 5-9 *in* H.M. Shelton and W.W. Stür eds. Forages for plantation crops. Proc. of Workshop, ACIAR Proc. 32 Australian Centre for International Agricultural Research, Canberra, Australia.

Shelton, H.M., T.R. Evans and T. Cowan. 1985. Relevance of Australian experience in tropical pastures to developing countries. Proc. 3rd Aust. Conf. on Tropical Pastures. pp 160-168.

Sophansdora, P. and S. Tudori. 1990. Integration of forages for cattle and goats into plantation systems in Thailand. Pages 147-150 *in* Khon Kaen University Pasture Improvement Project Annual Report 1990.

Stür, W.W., A.G. Cameron and J.B. Hacker. 1995. Forages for Smallholders-Proceedings of the Third Meeting of the Southeast Asian Regional Forage Seeds Project. Samarinda, Indonesia, 23-28 October 1994. CIAT Working Document No, 143. CIAT, Cali, Colombia. pp 149

Sukanten, I.W., I.M. Nitis, K. Lana, M. Suarna and S. Uchida. 1995. Growth and fodder yield of the *Gliricidia sepium* provenances in alley cropping system in dryland farming area in Bali, Indonesia. Asian-Australasian J. Anim. Sci. **8:** 195-200.

Tajuddin, I., K.F. Ng and D.T. Chong. 1991. The potential and prospects for improving forage production under rubber in Malaysia. Pages 130-33 *in* H.M. Shelton and W.W. Stür eds. Forages for plantation crops. Proc. of Workshop, ACIAR Proc. 32 Australian Centre for International Agricultural Research, Canberra, Australia.

Tham, K.C. and P.C. Kerridge. 1982. Responses to lime, K, Mo, and Cu by grass-legume pastures on some utisols and oxisols of Peninsula Malaysia. MARDI Res. Bull. **10:** 350-369

Tuhulele M. 1997. A farmer's experience of oversowing legumes. SEAFRAD News. Issue 4 p. 3.

Topark-Ngarm, B. and R.L. Aitken. 1982. Potassium in Northeast pasture soils. Pages 70-71 *in* Khon Kaen University Pasture Improvement Project Annual Report 1981-82.

Various. 1990 A series of papers published in Tropical Grasslands Volume 24.

Vera, R.R., R.J. Thomas, L. Sanint and J.I. Sanz. 1992. Development of sustainable ley-farming systems for the acid-soil savannas for tropical America. An. Acad. Brasil. Cienc. 64 (Suppl. 1): 105-125.

Wilaipon, B. and Wilaipon, N. 1982. Comparative study of yield of *Stylosanthis hamata* cv. Verano and *Stylosanthes humilis* CPI 61674 under different levels of soil fertility. Pages 76-78 *in* Khon Kaen University Pasture Improvement Project Annual Report 1981-82.

Wilson, J.R., K. Hill, D.M. Cameron and H.M. Shelton. 1990. The growth of *Paspalum notatum* under the shade of a *Eucalyptus grandis* plantation canopy or in full sun. Trop. Grass. **24:** 24-28.

Winks, L. 1990. Phosphorus and beef production in northern Australia. 2. Responses to phosphorus by ruminants-a review. Trop. Grass. **24:** 140-158.

Winter, W.H., D.B. Coates, R.E. Hendricksen, P.C. Kerridge, R.W. McLean and C.P. Miller. 1990. Phosphorus and beef production in northern Australia. 4. The response of cattle to fertilizer and supplementary phosphorus. Trop. Grass. **24**: 170-184.

Xavier, D.F. and R.M. Boddey. 1995. Screening of *Pennisetum purpureum* accessions having the potential for biological N fixation. Pages 240-241 *in* R.M. Boddey, A.S. de Resende and R.J. Angra dos Reis eds. International Symposium on Sustainable Agriculture in the Tropics - the Role of Biological Nitrogen Fixation.

Zahari, A.B., K.C. Tham, N.C. Wong and P.C. Kerridge. 1983. Sulfur deficiencies in the agriculture of Malaysia. Pages 155-164 *in* G.J. Blair and A.R. Till eds. Sulfur in South East Asian and South Pacific Agriculture. The University of New England, Armidale, Australia.

Table 1
Ruminant population in 1994 (x 1000) and % change from 1979/81 and in S.E. Asia, Tropical America and Australia. (FAO, 1997)

	Cattle		Buffalo		Sheep		Goats	
COUNTRY	**1994**	**% change**	**1994**	**% Change**	**1994**	**% Change**	**1994**	**% Change**
S.E. ASIA								
MYANMAR	9691	13	2130	12	304	29	1113	70
CAMBODIA	2589	220	829	120	0	0	0	0
INDONESIA	11010	69	3109	26	6485	57	11886	52
LAOS	1137	160	1308	57	0	0	153	234
MALAYSIA	721	34	166	-40	249	281	305	-14
PHILIPPINES	1936	3	2560	-10	30	0	2633	66
THAILAND	7593	80	4982	-16	91	263	141	165
VIET NAM	3467	105	2961	27	0	0	428	125
AVERAGE		55		6		59		56
TROPICAL AMERICA								
MEXICO	30702	11	0	0	5905	-9	10450	8
COSTA RICA	1894	-13	0	0	3	9	2	19
EL SALVADOR	1236	0	0	0	5	30	15	9
GUATEMALA	2300	22	0	0	440	-28	78	6
HONDURAS	2050	4	0	0	13	163	28	16
NICARAGUA	1730	-27	0	0	4	49	6	-1
PANAMA	1454	3	0	0	0	0	5	-17
BOLIVIA	5912	3	0	0	7886	-15	1479	-26
BRAZIL	158243	33	1571	22	18436	3	10879	31
COLOMBIA	25700	7	0	0	2540	6	960	49
ECUADOR	4937	65	0	0	1690	47	369	44
PERU	4062	-4	0	0	12160	-10	1790	5
VENEZUELA	13796	31	0	0	850	155	2369	76
AVERAGE		19		-2		-3		15
AUSTRALIA	**25732**	**-2**	**0**	**0**	**133000**	**-2**	**200**	**14**

Table 2
Feeding and forage systems in use in four regions of Java Indonesia (Semali, 1988)

	Sukanagara	Mentoro	Ngampin	Randubango
Livestock density (LU/km^2)	21	88	44	67
Human density (/km^2)	513	648	1258	1551
<u>Feeding System (%)</u>				
Cut-and carry	37	98	98	47
Tethered grazing	21	2	0	39
Limited grazing	39	0	2	15
Free grazing	5	0	0	0
<u>Feed collected from (%)</u>				
Own land	42	16	46	10
Other land	58	84	54	90
<u>Feed source (%)</u>				
Rice land	45	40	28	7
Dry land	22	8	34	1
Rice bunds	6	46	39	67
Pasture	14	2	3	0

Table 3
Ownership and feeding systems for large ruminants in Thailand (Phaikaew C. personal communication)

Livestock Type	Ownership		Feeding System
Beef cattle	Commercial	10%	50% grassland grazing + 50% cut and carry
	Smallholder	90%	90% grassland grazing + 10% cut and carry
Dairy Cattle	Commercial	50%	50% grassland grazing + 50% cut and carry + some crop residues
	Smallholder	50%	100% cut and carry with some crop residue
Buffalo	Commercial	0	
	Smallholder	100$	70% grassland grazing + 10% cut and carry + 20% crop residues