The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. Its mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australian and developing country researchers in fields where Australia has a special research competence.

ACIAR PROCEEDINGS

The series of publications includes the full proceedings of research workshops or symposia organised or supported by ACIAR. Numbers in this series are distributed internationally to selected individuals and scientific institutions. Recent numbers in the series are listed inside the back cover.

Copland, J.W., Djajanegra, A., and Sabrani, M., ed. 1994. Agroforestry and Animal Production for Human Welfare: proceedings of an international symposium held in association with the 7th AAAP Animal Science Congress, Bali, Indonesia, 11–16 July 1994. ACIAR Proceedings No. 55, 125p.

ISBN 1 86320 133 5

Typesetting and layout: Arawang Information Bureau Pty Ltd, Canberra, Australia.
Printing:

Agroforestry and Animal Production for Human Welfare

Proceedings of an international symposium held in association with the 7th AAAP Animal Science Congress, Bali, Indonesia, 11–16 July 1994

Editors: J.W. Copland, A. Djajanegra and M. Sabrani

Australian Centre for International Agricultural Research
Canberra 1994

Contents

Opening Address

THE theme of the 7th AAAP Animal Science Congress 'Sustainable Animal Industries and the Environment' is important both to Indonesia and the world. In the Indonesian setting it is important to national development with regard to forest industries, livestock and hence the maintenance of a sustainable environment. With regard to long-term development, governments of the AAAP region are encouraged to manage and sustain forests and improve their function. Vast areas of forest land, pasture and swamp are now being exploited and continue to be regarded as a resource important for economic development and the improvement of farmers' incomes. In this regard, we have to be aware that over-exploitation and mismanagement of resources may endanger the ecosystem and hence the wider environment.

It has become increasingly clear that forest and land managment should be environmentally orientated in order to maintain a sustainable long-term productivity. In doing so, management needs to take account of the social, physical and economic realities of human welfare. Besides maintaining and sustaining forest and pasture environments, we also realise the need for increased food production is urgent, and the competition between different objectives, if not well managed, can lead to environmental degradation.

I believe that the various studies that have been conducted by scientists in the AAAP region and other parts of the world can contribute to solving present and future problems. The problem of communicating research results and hence the rate of adoption is often a serious constraint.

Today in this symposium, we have the opportunity to explore the evidence, experiences and information which can provide alternatives in developing agroforestry and animal production systems which will contribute to improved human welfare.

ACIAR has its primary mission to improve agricultural production through collaboration in scientific endeavour, and has agreed to participate in our effort to expand our scientific horizon in the development process. We are very pleased to host this symposium which is multi-disciplinary, and multi-institutionally organised. The topics presented in this symposium are highly relevant. We hope that this meeting will provide a forum for establishing international understanding and positive interaction in order to be able to formulate active regional research collaboration and communication. We expect that the symposium can produce alternative approaches to the development of animal–agroforestry industries, aimed at producing appropriate technology and policy.

Finally, I would like to congratulate all of you and thank you for your active participation. I hereby have the pleasure to declare this symposium open and wish you good luck.

Soetatwo Hadiwigeno
Secretary General
Department of Agriculture
Republic of Indonesia

Animal Production Potential of Agroforestry Systems

R.C. Gutteridge and H.M. Shelton*

Abstract

This paper reviews the animal production potential of agroforestry systems. Factors influencing animal productivity include the forage contribution from tree and nontree sources, competition between tree and understorey, compatibility between tree crop and animals, and the service role of the tree in ameliorating the microclimate of the animal. Animal productivity ranges from highly productive in systems where the tree forms the primary source of animal forage to poorly productive in silvopastoral situations where the animal is of secondary importance dependent on an underused resource within the system.

THE positive benefits of integrating domestic farm animals in agroforestry systems are increasingly being recognised. Synergistic associations between trees and animals occur due to increased forage supply, or for other reasons such as shade and shelter for animals, improved nutrient recycling, and stabilisation of sloping lands. There is potential for more diversified and increased production and greater economic returns, and therefore longer-term sustainability and productivity of agricultural systems.

Agroforestry has been defined by ICRAF as 'a collective name for land-use systems and technologies, where woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions between components'.

There are two major systems which integrate animals. Agrosilvopastoral systems combine crops, animals and trees while silvopastoral systems involve trees and animals. Within both systems, the production emphasis may be placed on any component and this balance affects the animal production potential of the system.

* Department of Agriculture, The University of Queensland, Brisbane, Queensland 4072, Australia.

The upper limit for animal production from these systems is influenced largely by the use and role placed on the tree component of the system. If the tree is used primarily as a source of feed for the animal, then the potential for animal production is quite high. However, if the major focus of the system is to produce a tree product (timber, fruit, bark) then the potential for animal production can be low—the animal is usually only a secondary component.

The factors affecting animal production potential of agroforestry systems and the range of successful systems in use will be discussed in this paper.

Factors Affecting Forage and Animal Productivity of Agroforestry Systems

Forage contribution from nontree species

In most agroforestry systems involving livestock, the nontree source of forage will be either natural grasses and herbs, planted grasses and legumes, planted leguminous cover crops, or crop residues. The yield of the nontree component is usually limited by competitive interference from the more dominant tree component and determined by tree density and canopy characteristics.

In Australia, vast areas (2.62 million km^2) of eucalypt woodland are grazed in a natural agroforestry system where native grasses such as *Heteropogon contortus*, *Bothriochloa* spp., *Themeda* spp. and *Sorghum* spp. are the dominant feed source. The trees are often thinned to reduce competition with the understorey for moisture and to increase pasture growth. This increase may be up to three-fold (Walker et al. 1972). The quality of the forage from the understorey is generally very poor except for short periods at the beginning of the wet season. Quality can be improved by oversowing adapted legumes such as *Stylosanthes* spp. and application of phosphorus fertilizers (Miller et al. 1988). In areas with more favourable climatic conditions and higher soil fertility the native grass species can be replaced with improved grasses such as *Chloris gayana*, *Panicum maximum* or *Cenchrus ciliaris*, but this generally involves complete removal of trees (Miller et al. 1988). Similar extensive woodland grazing systems where native pastures are the dominant feed source are found in southern Africa and South America.

Forage contribution from the tree species

Trees and shrubs provide valuable fodder to domestic herbivores (Pandey 1982; Robinson 1985). At least 75% of the shrubs and trees of Africa serve as browse plants, while in South America and Australia, natural stands of trees such as *Prosopis* and *Acacia* sustain the pastoral industries of arid regions in drought.

Genuinely productive agroforestry systems with animals involve tree legumes which provide high yields of quality forage. The principal species used for this purpose are shown in Table 1. Species are available to suit a wide range of environmental and management requirements; however, the quality of forage tree legumes varies greatly from very high (*Leucaena leucocephala*) to quite low (*Acacia aneura*) (Norton 1994).

The leaves, flowers, pods and fine stems form the edible component of tree and shrub species and the nutritive value of this material is related to intake, digestibility, chemical composition and the presence or absence of antinutritive factors. The pods in particular are a valuable high protein forage source for livestock, especially in dry periods. Felker and Bandurski (1979) suggested that species such as *Prosopis* sp. *Gleditsia triacanthos* and *Faidherbia albida* could produce from 3–10 t pods/ha depending on the ecological zone and tree density.

Under natural conditions, a large proportion of the foliage of tree species is out of reach of the grazing animal, so that cutting or lopping may be necessary. Natural leaf fall through senescence also can be an important component of the diet of some grazing animals. In Africa, goats thrive on the leaf fall of *Acacia meliflora* (Dougall and Bogdan 1958). Lowry (1989) reported that the leaf and pod fall from *Albizia lebbeck* in naturalised stands in northern Australia could be an important supplement to grazing cattle.

The dry matter digestibility (in sacco and in vitro) of tree legume leaf varied from high (>60% for *Sesbania sesban*, *Leucaena leucocephala* and *Gliricidia sepium*) through moderate (50–60% for *Albizia lebbeck* and *Codariocalyx gyroides*) to low (30–50% for *Albizia chinensis*, *Acacia aneura* and *Calliandra calothyrsus*) (Bamualim 1981; Robertson 1988; Vercoe 1987).

Table 1. The chemical composition (g/kg dry matter) of foliage from a range of tree legume species (after Norton 1994).

Species	Crude protein	Ash	NDF	ADF	Lignin	Tannin
Acacia aneura	127[a]	42	504	396	200	57
Albizia lebbeck	214	72	-	-	-	ND[b]
Calliandra calothyrsus	193	41	281	219	77	104
Chamaecytisus palmensis	214	53	253	-	-	ND
Desmanthus virgatus	131	72	256	195	91	-
Faidherbia albida	172	65	-	-	-	-
Gliricidia sepium	233	67	353	259	82	25
Leucaena leucocephala	249	73	334	229	85	46
Sesbania grandiflora	273	105	-	238	81	ND
Sesbania sesban	206	85	219	153	-	-

[a] Values are the mean of range from Norton (1994).

[b] ND = none detected.

Secondary plant compounds such as tannins are present in the foliage of many tree species (e.g. *Calliandra calothrysus*, *Leucaena diversifolia*, *Acacia aneura*) and may reduce the digestibility of protein and limit the intake of the forage by ruminants (Norton 1994).

The nutritional quality of *Leucaena leucocephala* is regarded as excellent (Jones 1979). This can be related to a number of factors including excellent palatability and digestibility, balanced chemical composition of minerals and protein amino acids, low fibre content, moderate tannin content to promote bypass protein value, and a biological solution to the problem of toxicity of the nonprotein amino acid mimosine and its degradation products 3,4 and 2-3-hydroxy-pyridine (Jones and Lowry 1984).

Competition between trees and pastures

In general, trees compete with understorey herbaceous species and decrease the productivity of the understorey depending on tree species, climate and management factors. There are many examples.

McConnell and Smith (1970) reported that a linear relationship between pasture yield and basal area of coniferous forests accounted for 94% of the variation in understorey herbage yield. Studies on *Acacia aneura* (mulga) communities in subtropical Australia have shown similar relationships (Beale 1973; Pressland 1976).

Cameron et al. (1989) investigated the effects of increasing densities of *Eucalyptus grandis* on the productivity of understorey *Setaria*-dominant pasture. They found that pasture production was substantially reduced at densities over 2000 stems/ha as early as 1.5 years, and at densities over 300 stems/ha at 3.5 years. These data demonstrate the rapid change in light environment and resultant decrease in pasture yield as the trees age.

The outcome of competition can be modified by management practices such as plant density and thinning. Very wide spacings will increase herbage yields but sometimes at the expense of timber quality as trees tend to branch more at lower densities.

Shading effects on forage yield

The effect of reduced light penetration is possibly the most important factor affecting the tree–understorey relationship and therefore animal production potential.

Grass growth usually is increased when trees are removed. In Australia, this is due mainly to competition for water and nutrients (Scanlan and Burrows 1990). In Malaysia, in a favourable moisture and nutrient environment, the yield and botanical composition of understorey herbage was related closely to the incidence of photosynthetically active light (Table 2) (Tajuddin et al. 1993).

However, grass growth and yield under moderate shade has been shown, under certain circumstances, to be higher than in full sun. This 'shade response' occurs where growth of grass in full sun is restricted by N deficiency, and the effect of shade is increased N availability and therefore plant growth (Wilson and Wild 1991). Subsequent research showed that while some of the increased N availability was due to translocated N from roots to stems, the majority appeared to come from improved litter breakdown and mineralisation under shade (Wild et al. 1993).

Competition for moisture and nutrients

Many agroforestry mixtures are designed on the assumption that trees are deep rooted and access moisture and nutrients from greater depths than herbaceous plants. This is not always true. Differences in moisture depletion rates with depth exist even between tree species (Leyton 1983). While studies have shown that tree legumes are able to take up moisture from deeper layers, the majority of tree roots are in the top 50 cm and therefore in direct competition with herbaceous species (Nulik 1994). Similarly, soil nutrients are normally concentrated in the organic matter layer in the soil surface so that deep roots may confer no advantage in nutrient absorption.

Furthermore, rooting depth is not determined solely genetically but is affected by soil and climatic conditions. In acid soils roots tend to be concentrated in the surface soil to avoid subsoil acidity, leading to severe competition (Fernandes et al. 1990). Root pruning of hedgerows, shelterbelts or border trees can partially reduce competition but is not practical where trees are interspersed throughout a pasture or cropping area.

More research is necessary to clarify competitive relationships between species in agroforestry systems.

Table 2. Forage productivity of cover crops and naturally occurring vegetation under rubber (after Tajuddin et al. 1993).

Light transmission (% PAR)	>80	80–50	50–20	<20
Dry matter production (t/ha/year)	5.5	4.7	1.0	0.3

Tree canopy effects on temperature, relative humidity and wind speed

In the tropics, most attention has been focused on providing better feeding to improve animal production, but there is increasing recognition of the deleterious effects of extreme heat and high relative humidity. Both growth and reproductive performance of ruminants can be adversely affected (S. Petty, pers. comm.).

Under extreme heat, animals seek shade and intake is reduced. Agroforestry can ameliorate environmental extremes; air temperatures under shade are generally lower than in open sunlight (Chen 1989; Ovalle and Avendamo 1988).

The effect of heat stress on fertility levels in both sheep and cattle has been well documented. Daly (1984) recorded a reduction of 0.9% in calving rate for every 0.1°C increase above 39°C in the rectal temperature of cows. The average depression in calving rate due to heat stress was 15 to 25% for British breeds and 10% in Brahman cross herds. Stressed cows also gave birth to lighter calves. Davison et al. (1988) found that the provision of tree shade increased mean daily milk yields of dairy cows by 2 kg/cow and that animals without shade had a mean rectal temperature of 40°C while those with shade had a rectal temperature was 39.4°C.

In temperate regions, trees can ameliorate the 'wind chill factor' and greatly reduce mortality of vulnerable livestock such as newly shorn sheep in southern Australia (Bird and Cayley 1991).

Suitability of animal species for agroforestry

Cattle and sheep are well suited to incorporation into most silvopastoral systems. Both species are essentially grazers and usually will consume the understorey herbaceous plants in preference to browsing trees and shrubs—unless herbage is dominated by unpalatable species. However, in all agroforestry systems, livestock need to be excluded from areas containing very young trees until the leaf canopy is out of reach of the animal.

One advantage of grazing cattle in tree plantations is weed and grass control. In coconut plantations, collection of fallen nuts is facilitated and nut recovery rates are much higher in grazed plantations. In Malaysia, it was estimated that the grazing of sheep in rubber plantations resulted in a saving of approximately 30% of the costs of chemical weed control as well as reduced chemical hazard (Tajuddin et al. 1990).

Incompatibility between trees and animals is based on unacceptable damage to either component or interference in the management of the tree crop (Stür and Shelton 1991).

Goats are essentially browsers and are less suited to agroforestry systems involving direct grazing of forages in the presence of trees. Some tree species are particularly susceptible to browsing by goats. P.R.D. Philp (pers. comm.) reported that young *Sesbania grandiflora* trees growing on rice paddy bunds were completely destroyed by goats browsing in the dry season in Sumbawa, Indonesia. At Mt Cotton, southeast Queensland, goats caused 75% mortality in a stand of *Sesbania sesban* trees by ringbarking the stem 10–15 cm above ground level (Kochapakdee 1991).

Goats can be included in agroforestry systems if they are tethered or housed. In the southern Mindanao region of the Philippines, an economically viable cut and carry system has been developed by the Mindanao Baptist Rural Life Centre (Laquihon and Pagbilao 1994). Stands of the tree legumes *Leucaena leucocephala*, *Flemingia macrophylla* and *Desmodium rensonii*, grown in an alley cropping system with crops, are cut and fed to milking goats.

However, bark damage sometimes occurs with species other than goats. Sheep damage to the bark of young rubber has been observed in Malaysia (I. Tajuddin, pers. comm.). Rams in particular cause damage when sharpening their horns. Cattle grazing in forestry plantations caused damage to the bark of *Eucalyptus deglupta* in the Solomon Islands. This doubled the incidence of decay fungi entering the lower trunks of the trees (Shelton et al. 1987).

Direct damage to stems of mature coconuts or oil palms is minimal although there are concerns over possible soil compaction (Chen et al. 1978) and increased erosion hazard that might occur at higher stocking rates. Rubber root damage has been observed in some areas in Malaysia (I. Tajuddin, pers. comm.). Cattle are incompatible in rubber plantations as they disturb the tapping cups.

There are also some negative effects of tree crops on the grazing animal. Sheep in oil palms suffer from an abnormally high proportion of cuts due to the sharp spines on the petioles of fallen fronds (I. Tajuddin, pers. comm.).

A number of timber trees such as *Erythrophloeum succirubrum* have poisonous foliage and livestock should not be allowed access to plantations of this type.

Nonruminants are not used widely in agroforestry systems. Horses and poultry are used sometimes in specialised situations while pigs are regarded as too destructive to be included in systems incorporating trees.

Productivity of Animals in Agroforestry Systems

Silvopastoral

Natural silvopastoral systems

Plant communities dominated by woody plants are common. The subhumid savannas defined by Jones et al. (1984) are largely extensive woodland areas and are the principal grazing resource of the world's herbivores.

Natural silvopastoral systems can be broadly divided into two major types: those in which the woody species make no contribution to the grazing resource; and those in which the tree species provide edible browse.

Beef cattle are the main livestock enterprise in the natural woodland communities of Australia. Stocking rates range between 25 and 30 ha/beast on poor fertility monsoon tallgrass areas, giving liveweight gains of 65–90 kg/hd/year. In the moderate fertility low rainfall black spear grass regions, stocking rates vary between 3 and 15 ha/beast and liveweight gains range 90–120 kg/hd/year (Scattini et al. 1988).

Productivity of woodland communities is improved when naturally occurring browse trees are present. It is estimated that the dry savanna areas of subSahelian Africa can support approximately 10 cattle/km^2. This can be increased to 18–20 hd/km^2 where the native tree species *Faidherbia albida* (sym. *Acacia albida*) produces protein rich pods and high quality forage used primarily at the end of the dry season.

The carrying capacity of mulga lands (*Acacia aneura*) in southwest Queensland varies between 2 and 6 merino sheep/ha, but mulga, a poor quality forage, is only used in times of drought (Scattini et al. 1988).

Exotic trees in silvopastoral systems

In central Queensland, over 35000 ha of hedgerow-managed *Leucaena leucocephala* has been planted in a highly productive intensive silvopastoral system. The leucaena is sown in wide-spaced rows 4–10 m apart and an improved grass such as *Chloris gayana*, *Panicum maximum* or *Cenchrus ciliaris* is sown between the leucaena rows. High stocking rates of up to 0.6 to 1 steer/ha and liveweight gains of 255–330 kg/hd/year can be achieved with this very productive and sustainable system (Middleton et al. 1994).

In the Ord River district of northwestern Western Australia, an even more highly productive irrigated leucaena system has been developed. Leucaena is grown in 2–3 m rows with pangola grass (*Digitaria eriantha* spp. *pentzii*) between the rows. The area is stocked at 6–7 steers/ha and grazed rotationally. Animal daily liveweight gains range from 0.5 (winter) to 0.85 kg (summer), with a yearly production of 1500–1730 kg liveweight/ha (Pratchett and Triglone 1989).

Other tree species also have been investigated for use in extensive grazing systems. Gutteridge and Shelton (1991) reported liveweight gains of 0.70 kg/hd/day over 15 months for young heifers grazing a mixed *Sesbania sesban*/*Brachiaria decumbens* pasture in southeast Queensland. This compared with liveweight gains of 0.40 kg/hd/day for similar cattle grazing *B. decumbens* alone, fertilized with 200 kg N/ha/year.

There are reports of similar systems being developed in southern Africa and South America.

Plantation crop systems

The principal plantation crops where integration of livestock is possible are rubber, oil palm and coconuts. In the past, most attention has focused on the integration of cattle with coconuts and this system has the greatest potential for further development (Shelton 1991). The unique quality of coconuts, compared to most other plantation crops, is the relatively constant and bright light environment over the life of the crop (60–80 years). Consequently, understorey pastures can be grazed on a semi-permanent basis. Liveweight gain potential can be quite high and is influenced by a number of factors but particularly light level (Table 3). Improvement is possible through the use of shade-tolerant pasture species.

There is increasing interest in the grazing of sheep in rubber and oil palm plantations. In Malaysia, the productivity of sheep under rubber has been extensively investigated (Tajuddin et al. 1993). Experiments showed that productivity was moderate under young rubber (2–5 years) provided palatable leguminous cover crops were grazed, but low under mature rubber where light levels had fallen to <20% transmission of photosynthetically active light (Table 4). There is scope to increase productivity by using shade-tolerant forage species and by altering the conventional rubber planting system to a hedgerow format and this is being investigated (Tajuddin et al. 1993).

Forestry systems

Successful forest grazing systems based on *Pinus radiata* and sheep have been developed for the temperate regions of southern Australia and New Zealand. Sheep are preferred because they are less inclined to browse the trees than cattle. Stocking rates vary between 12 and 25 animals/ha in the early stages of tree development, but are negatively related to tree age and need to be reduced by at least 50% by year 10 (Knowles 1975).

Table 3. A summary of cattle liveweight gain data from grazing experiments under coconuts (after Shelton 1991).

Country (rainfall)	Pasture	Transmission of Light (%)	Liveweight gain (kg/ha)	Stocking rate (beasts/ha)	Reference
Solomon Islands (2900 mm/year)	Natural	60	235–345	1.5–3.5	Watson and Whiteman 1981
	Improved	60	227–348	1.5–3.5	Smith and Whiteman 1985
	Natural	62	219–332	1.5–3.5	
	Improved	62	206–309	1.5–3.5	
Western Samoa (2929 mm/year)	Natural	50	148	1.8	Reynolds 1981
	Improved	50	225–306	1.8–2.2	
	Natural	70–84	127	2.5	Reynolds 1981
	Improved	70–84	273–396	2.5	
Indonesia (1709 mm/year)	Improved	79	288–505	2.7–6.3	Rika et al. 1981
Thailand (1600 mm/year)	Natural	n.a.	44	1.0	Manidool 1983
	Improved	n.a.	94–142	1.0–2.5	
Vanuatu (1500 mm/year)	Improved	n.a.	175	1.5	Mcfarlane and Shelton 1986

Table 4. Liveweight gain of sheep grazing immature and mature rubber (after Tajuddin et al. 1993).

Stocking rate (sheep/ha)	Immature rubber[a]		Mature rubber[b]	
	g/hd/day	kg/ha/year	g/hd/day	kg/ha/year
2	–[c]	–	99	72
4	106	155	26[d]	38
6	97	212	19[d]	42
8	86	251	11[d]	32
10	83	303	–	–
12	*[e]	*	–	–
14	84	429	–	–

[a] Average of three drafts.

[b] Average of two drafts.

[c] Stocking rate not included in this experiment.

[d] Sheep had to be taken off for various periods to allow the pasture to recover.

[e] Sheep had to be withdrawn early because of a high proportion of *C. caeruleum*.

In the tropics, forest grazing systems have been less successful. In the Solomon Islands, pastures and cattle under *Eucalyptus deglupta* plantations at densities of 130 stems/ha could not be sustained in the long term (Shelton et al. 1987). In a young plantation (trees 2–3 years old), a stocking rate of 2.5 beasts/ha, giving liveweight gains of 0.45 kg/hd/day was achieved; however, by year 7 with almost complete tree canopy cover, stocking rates had to be reduced to less than 1 beast/ha, producing only 0.25 kg/hd/day liveweight. Substantial damage to the trees due to bark stripping by the cattle also occurred.

Animal production in forest plantations is therefore transient unless the trees are widely spaced, permitting ample light penetration to the pasture.

Horticultural systems

A number of other tree crop species such as mangoes, kapok, tamarind, cocoa and cashews have some potential for integration with livestock as they are usually planted on a wide spacing (10×10 m or 8×8 m) which promotes good light penetration especially in young crops.

The animal production potential from these systems, although not well documented, would not be high because of the precautions necessary to prevent damage to the often palatable leaves of the crop and the low light profile when the trees reach maturity.

A specialised agrosilvopastoral horticultural system in Bali is vanilla production under coconuts—the vanilla orchid is supported and shaded by the tree legumes *Gliricidia sepium* or *Erythrina* sp. The shade level is regulated by lopping the branches of the legume which are then fed to livestock (Mendra et al. 1991).

Agrosilvopastoral systems

Alley farming

The inclusion of livestock into alley farming systems necessitates that farmers change their tree management and foliage use practices. The daily demands of animals for feed require tree pruning at times unnecessary for cropping. Thus in alley farming, prunings taken at or near crop planting are used as mulch for the crop while all or part of later prunings can be used for animal feed.

At Ibadan in Nigeria, Reynolds and Atta-Krah (1986) suggested that the surplus foliage from 1 ha of *Leucaena leucocephala* and *Gliricidia sepium* from alley farming could provide half the daily fodder requirements for 29 goats. In the dry season fallow period, livestock can be allowed direct access to the cropping area to graze crop residues and browse the trees *in situ*. In Malawi, Savory et al. (1980) reported that a 0.25 ha leucaena alley farm produced enough leaf material to feed three dairy cattle 3 kg/DM/hd/day during the dry season.

In lowland humid regions of the tropics where farm size is often small, the amount of forage generated from alley farming is very low (ILCA 1987). However, in semi-arid regions, Singh et al. (1989) suggested that the additional forage from both prunings and crop residues may be the major incentive attracting farmers to use the alley farming technique.

Trees in cropping systems

In the more intensive agricultural areas of Asia and Africa where land is scarce and livestock are raised in small numbers by smallholder farmers, forage tree legumes are planted as 'fodder banks' along border or fence lines, and on rice paddy bunds or in home gardens. Foliage from these trees is usually harvested under a 'cut-and-carry' system and is a principal source of high quality fodder to supplement low quality roughages such as crop residues. In China, the leaf of the deciduous tree *Paulownia* spp., grown over an area of 1.8 million ha of cropping land, is collected in autumn and fed to cattle, sheep and pigs (Zhaohua 1991).

In parts of Africa, the incorporation of tree legumes in cropping areas has been described as 'the bedrock of traditional agroforestry systems in Africa' (Atta-Krah 1993). The trees are occasionally lopped for feed and are grazed in the dry season. Animal productivity is generally low. In the Batangas region of the Philippines, a 2-ha area of *Leucaena leucocephala* grown in association with the fruit tree *Anona squamosa* was able to supply the forage requirements of 20 growing cattle over a 6-month period (Moog 1986).

Three strata systems

The three strata forage system is an integrated agroforestry practice developed in Bali, Indonesia (Nitis 1986). It enhances crop and livestock production through the provision of forage, to supplement crop residues from the cropping area, from a combination of pastures, shrubs and trees. The system comprises three tiers or strata of forage grown as borders in an upland cropping system.

The system aims to produce a constant high quality feed supply throughout the year. The first stratum of herbaceous grasses and legumes supplies forage from the early wet to the early dry season; the second stratum of tree legumes provides forage for the early dry to the mid-dry season while the third stratum of taller trees covers the period mid-dry to early-wet.

Results indicated that the three strata system produced 90% more feed and carried a 29% higher stocking rate in the wet season and 46% higher stocking in the dry season compared to the traditional system. The growth rate of animals from both systems

Table 5. The potential productivity of agroforestry systems, by component.

System	Component/productivity				
	Crop	Forage	Animal	Timber	Fuelwood
Silvopastoral systems					
Natural Silvopastoral					
without edible browse	–	M	M/L	M	M
with edible browse	–	M/H	M	M	M/H
Plantation crops	H	M/L	M/L	L	M/L
Forestry systems	–	L	L	H	M/H
Horticultural systems	H	L	L	–	L
Tree legume hedgerows	–	H	H	L	M
Agrosilvopastoral systems					
Trees in crops	H/M	M/L	M/L	M	M
Alley farming	H	M	M/L	–	M
Three strata system	H	H	M	M	M
Trees in crops	H/M	M/L	M/L	M	M

H— high; H—medium; L—low

was similar. Although crop production was reduced slightly in the tree strata system, an economic analysis of both systems indicated that profitability was higher and risk more widely spread in the three strata system.

This system would appear to have wide applicability outside the Bukit Peninsula where it was tested. The environmental conditions there (1000 mm rainfall, long dry season 7–8 months) are similar to many other regions of the semi-arid tropics.

Summary and Conclusions

There is substantial potential for animal production in animal-based agroforestry systems and a number have been designed specifically to improve or enhance animal productivity. The major agroforestry systems covered in this paper and their potential productivity is outlined in Table 5. High levels of production are only possible through the use of high quality fodder-tree legumes when livestock production is the major economic activity. Further evaluation of the existing tree legume germplasm will broaden the resource base available and enable the expansion of these systems into a wider range of agroecological environments.

The animal production potential of forest and plantation crop grazing systems is relatively low and improvements in these systems will come largely from the identification and selection of herbaceous forage species tolerant of lower illuminance. Improvement is also possible through changes in plantation management practices such as tree spacing and pruning regimes.

In all systems the service role of the trees in providing shade and shelter must be taken into account as this aspect is often undervalued in assessing the productivity of agroforestry systems.

References

Atta-Krah, A.N. 1993. Trees and shrubs as secondary components of pasture. Proceedings of the XVII International grassland Congress, 2045–2052.

Bamualim, A. 1981. Nutritive value of some tropical browse species in the wet and dry tropics. M.Sc. thesis, James Cook University of North Queensland.

Beale, I.F. 1973. Tree density effects on yield of herbage and tree components in Southwest Queensland mulga (*Acacia aneura* F. Muell.) scrub. Tropical Grasslands, 7, 135–142.

Bird, P.R. and Cayley, J.W.D. 1991. Bad weather, shelter and stock losses. Agricultural Science, 4, 18–19.

Cameron, D.M., Rance, S.J., Jones, R.M., Charles-Edwards, D.A. and Barnes, A. 1989. Project STAG: an experimental study in agroforestry. Australian Journal of Agricultural Research, 40, 699–714.

Chen, C.P. 1989. Problems and prospect of integration of forage into permanent crops. In: Halim, R.A., ed., Grasslands and forage production in South-East Asia. Proceedings First Meeting Regional Working Group on Grazing and Feed Resources of South-East Asia, Serdang, Malaysia, 128–139.

Chen, C.P., Chang, K.C., Singh Sidhu, A. and Wahab, Hassan 1978. Pasture and animal production under five year old oil palm at Serdang. Proceedings of Seminar on Integration of Animals with plantation Crops, Pulan, Pingang Malaysia 16, 1–12.

Daly, J.J. 1984. Cattle need shade trees. Queensland Agricultural Journal, 110, 21–24.

Davison, T.M., Silver, B.A., Lisle, A.T. and Orr, W.N. 1988. The influence of shade on milk production of Hostein-Friesian cows in a tropical upland environment. Australian Journal of Experimental Agriculture, 28, 149–154.

Dougall, H.W. and Bodgan, A.V. 1958. Browse plants of Kenya with special reference to those occurring in South Baringo. The East African Agricultural Journal, April, 236–245.

Felker, P. and Bandurski, R.S. 1979. Uses and potential uses of leguminous trees for minimal energy input agriculture. Economic Botany 33, 172–184.

Fernandes, E.C.M., Davey, C.B. and Sanchez, N.C. 1990. Alley cropping on an utisol: mulch, fertilizer and hedgerow root pruning effects. Agronomy Abstracts, (1990), 56.

Gutteridge, R.C. and Shelton, H.M. 1991. Evaluation of *Sesbania sesban* —a new forage shrub species for tropical and subtropical Australia. Final Technical Report, Meat Research Corporation, Canberra 12 p.

ILCA (International Livestock Centre for Africa). 1987. Anual Report 1986–87 ILCA, Addis Ababa, Ethiopia.

Jones, R.J. 1979. The value of *Leucaena leucocephala* as a feed for ruminants in the tropics. World Animal Review, 31, 13–23.

Jones, R.J. and Lowry, J.B. 1984. Australian goats detoxify the goitrogen 3-hydroxy-4(IH) pyridone after rumen infusion from Indonesian goats. Experimentia, 40, 1435–1436.

Jones, R.M., Tothill, J.C. and Jones, R.J. 1984. Pastures and pasture management in the tropics and subtropics. Tropical Grassland Society of Australia Occasional Publication No 1.

Knowles, R.L. 1975. Trees and grass. Farm Forestry, 17, 63–74.

Kochapakdee, S. 1991. An evaluation of browse trees in the grazing management of breeding does and kids. M.Agr.Sc. thesis, The University of Queensland.

Laquihon, W.A. and Pagbilao, M.V. 1994. Sloping Agricultural Land Technology (SALT) in the Philippines. In: Gutteridge, R.C. and Shelton, H.M., ed., Forage tree legumes in tropical agriculture. Wallingford, U.K., CAB International, 366–373.

Leyton, L. 1983. Crop water use: principles and some considerations for agroforestry. In: Huxley, P.A., ed., Plant Research and Agroforestry, ICRAF, Nairobi, Kenya, 379–400.

Lowry, J.B. 1989. Agronomy and forage utilization of *Albizia lebbeck* in the semi-arid tropics. Tropical Grasslands, 23, 84–91.

Manidool, C. 1983. Pastures under coconuts in Thailand. In: Juang, T.C., ed., Asian pastures. Taipei, Taiwan, FFTC Book Series No 25.

McConnell, B.R. and Smith, J.G. 1970. Response of understorey vegetation to ponderosa pine thinning in eastern Washington. Journal of Range Management, 23, 385–399.

McFarlane, D. and Shelton, H.M. 1986. Pastures in Vanuatu. Canberra, ACIAR Technical Report 2.

Mendra, I.K., Rika, I.K., Gusti Oka, M. and Oka Nurjaya, M.G. 1991. Utilisation of forage resources from vanilla-growing areas under coconuts in Bali. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Canberra, ACIAR Proceedings No. 32, 38–40.

Middleton, C., Wildin, J.H., Petty, S., Jones, R.J. and Shelton, H.M. 1994. Potential for development and priorities for research into leucaena in Northern Australia. Proceedings of Workshop on Leucaena Research and Development, Bogor, Indonesia, 24–29 January 1994, in press.

Miller, C.P., Wildin, J.H., Cooksley, D.G. and Lowe, K.F. 1988. Augmenting native pastures with sown species. In: Burrows, W.H., Scanlan, J.C. and Rutherford, M.T., ed., Native pastures in Queensland. The resources and their management. Brisbane, Department of Primary Industries, 160–173.

Moog, F.A. 1986. Forages in integrated food cropping systems. In: Blair, G.J., Ivory, D.A. and Evans, T.R., ed., Forages in Southeast Asian and South Pacific agriculture. Canberra, ACIAR Proceedings No. 12, 152–156.

Nitis, I.M. 1986. Three strata system for cattle feeds and feeding in dryland farming area in Bali. Progress Report, Udayana University, Denpasar, Bali, Indonesia, 197 p.

Norton, B.W. 1994. The nutritive value of tree legumes. In: Gutteridge, R.C. and Shelton, H.M., ed., Forage tree legumes in tropical agriculture. Wallingford, U.K., CAB International, 177–191.

Nulik, J. 1994. Establishment of tree legumes as influenced by water stress, competition and phosphorus nutrition. Ph.D. thesis, The University of Queensland.

Ovalle, C. and Avendano, J. 1988. Interactions de la strate ligneuse avec le strate herbacee dans les formations d'Acacia caven (Mol) Hook. et Arn. au Chili II. Influence de l'arbre sur quelques elements du milieu: microclimat et sol. Oecologia Plantarum, 9, 113–134.

Panday, K.K. 1982. Fodder trees and tree fodder in Nepal Berne, Switzerland, Swiss Development Corporation, 107 pp.

Pratchett, D. and Triglone, T. 1989. Prospects for leucaena on the Ord. Western Australia Journal of Agriculture, 30, 62–66.

Pressland, A.J. 1976. Possible effects of removal of mulga on rangeland stability in south western Queensland. Australian Rangelands Journal, 1, 24–30.

Reynolds, L. and Atta-Krah, A.N. 1986. Alley farming with livestock. In: Kang, B.T. and Reynolds, L., ed., Alley farming in the Humid and Sub Humid Tropics. Proceedings of an International Workshop held at Ibadan, Nigeria, 22–36.

Reynolds, S.G. 1981. Grazing trials under coconuts in Western Samoa. Tropical Grasslands, 15, 3–10.

Rika, I.K., Nitis, I.M. and Humphreys, L.R. 1981. Effects of stocking rate on growth, pasture production and coconut yield in Bali. Tropical Grasslands, 15, 149–157.

Robertson, B.M. 1988. The nutritive value of five browse legumes fed as supplements to goats offered a basal rice straw diet. M.Agr.Studies thesis, The University of Queensland.

Robinson, P.J. 1985. Trees as fodder crops. In: Cannell, M.G.R. and Jackson, J.E., ed., Attributes of trees as crop plants. Huntingdon, U.K., Institute of Terrestrial Ecology, 281–300.

Savory, R., Breen, J.A. and Beale, C.I.A. 1980. Leucaena as a forage crop on small farms in Malawi. In: Le Houerou, H.N., ed., Browse in Africa. Addis Ababa, Ethiopia, ILCA.

Scanlan, J.C. and Burrows, W.H. 1990. Woody overstorey impact on herbaceous understorey in *Eucalyptus* spp. communities in central Queensland. Australian Journal of Ecology, 15, 191–197.

Scattini, W.J., Orr, D.M., Miller, C.P., Holmes, W.E. and Hall, T.S. 1988. Managing native grasslands. In: Burrows, W.H., Scanlan, J.C and Rutherford, M.T., ed., Native pastures in Queensland the resources and their management. Brisbane, Department of Primary Industries.

Shelton, H.M. 1991. Productivity of cattle under coconuts. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Canberra, ACIAR Proceedings No. 32, 92–96.

Shelton, H.M., Schottler, J.H. and Chaplin, G. 1987. Cattle under trees in the Solomon Islands. Brisbane, University of Queensland, 20 p.

Singh, R.P., Ong, C.K. and Saharan, N. 1989. Above and below ground interactions in alley cropping in semi-arid India. Agroforestry Systems, 9, 259–274.

Smith, M.A. and Whiteman, P.C. 1985. Animal production from rotationally grazed natural and sown pastures under coconuts at three stocking rates in the Solomon Islands. Journal of Agricultural Science Cambridge, 104, 173–180.

Stür, W.W. and Shelton, H.M. 1991. Compatability of forages and livestock with plantation crops. In: Shelton, H.M., and Stür, W.W., ed., Forages for plantation crops. Canberra, ACIAR Proceedings No. 32 112–116.

Tajuddin, I., Chong, D.T., Ng, K.F., Stür, W.W. and Shelton, H.M. 1993. Sheep and forage productivity in rubber plantations. Proceedings of the XVII International Grassland Congress, 2067–2068.

Tajuddin, I., Najib, L.A., Chong, D.T., Abd. Samat, M.S. and Vanaja, V. 1990. Status report RRIM Commercial Sheep Project, 1985–1988. Rubber Research Institute of Malaysia.

Vercoe, T.K. 1987. Fodder potential of selected Australian tree species. In: Turnbull, J.W., ed., Australian Acacias in developing countries. Canberra, ACIAR Proceedings No. 16, 95–100.

Walker, J., Moore, R.M. and Robertson, J.A. 1972. Herbage response to tree and shrub thinning in *Eucalyptus populnea* shrub woodland. Australian Journal of Agricultural Research, 23, 405–410.

Watson, S.E. and Whiteman, P.C. 1981. Animal production from naturalized and sown pastures at three stocking rates under coconuts in the Solomon Islands. Journal Agricultural Science Cambridge, 97, 669–676.

Wild, D.W.M., Wilson, J.R., Stür, W.W. and Shelton, H.M. 1993. Shading increases yield of nitrogen limited tropical grasses. Proceedings of the XVII International grassland Congress, 2060–2062.

Wilson, J.R. and Wild, D.W.M. 1991. Improvement of nitrogen nutrition and grass growth under shading. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Canberra, ACIAR Proceedings No. 32, 77–82.

Zhaohua, Z. 1991. Evaluation and model optimisation of Paulownia intercropping system — a project summary report. In: Zhaohua, Z., Nantang, C., Shiji, W. and Youxu, J., ed., Agroforestry systems in China. Ottawa, Canada, IDRC, 30–43.

Agroforestry Systems in the Humid Forest Margins of Tropical America from a Livestock Perspective

C.E. Lascano* and D.A. Pezo†

Abstract

Livestock is an important component of production systems in different agroecologies of tropical America. However, since the area in pastures was under natural forest, cattle production is not sustainable and has been associated with environmental degradation. Ecologically sustainable and economically attractive technologies capable of preventing further deforestation and of reclaiming large areas of degraded pastures in the forest margins of the region are needed. One solution is the integration of trees, pastures and livestock. In this paper, entry points for agroforestry systems in forest margins of tropical America are identified, some examples of existing and proposed livestock-based agroforestry systems are presented, and opportunities and some actions needed for the development and adoption of sustainable agroforestry systems are discussed. It is suggested that pastures based on mixtures of grasses and legumes adapted to major environmental constraints, and capable of persisting under heavy grazing, will contribute to reverse degradation in forest margins. This improved pasture technology could be the basis for the development of sustainable livestock-based agroforestry systems. The role of the forestry component in pasture–livestock systems is less clear due to the lack of quantitative information on the interactions of trees with animals in grazed pastures.

CATTLE raising is an important component of production systems in all major agroecosystems (savannas, hillsides, and forest margins) of tropical America. However, cattle production in the humid forest is controversial because of the environmental degradation caused by deforestation to establish pastures. Large-scale clearing for pasture establishment was triggered by the opportunity for beef export in Central America and southern Mexico (Myers 1981) and by economic subsidies in the eastern Amazon of Brazil (Hecht 1985; Serrao and Toledo 1990). These policies have been revised, but deforestation is still occurring at a fast rate in the Atlantic coastal plains in Central America, and the Amazon basin, which is being colonised by landless-poor people (Leonard 1987; Hecht 1993). It is estimated that the area deforested in the Amazon basin may already exceed 60 million ha (Anderson 1990), of which 50% is estimated to be under pastures carrying 23 million head of cattle (CIAT, unpublished results). It is this forest margin area on which attention is focused; the aim being to reduce pressure on primary forest.

Large and small producers in forest margins of the region view cattle not only as a secure source of income, but also as a means of extending the economic life of cleared areas (Hecht 1993). Therefore, there is an urgent need to research and promote technologies for livestock-based systems that are environmentally sound. One solution suggested by many researchers and developers is the integration of trees, pastures and livestock. The argument is that trees could provide tangible benefits (i.e. living fences, forage, fuelwood, timber, fruits) to the farmer and also contribute to soil enhancement through nutrient

* Tropical Forages Program, Centro International de Agriculture Tropical (CIAT), A.A. 6713, Cali, Colombia.

† MAG, San José, Costa Rica.

cycling (Vergara 1987; Nair 1987; Gutteridge and Shelton 1993).

In this paper we describe predominant production systems in cleared forest areas of tropical America and present some examples of existing livestock-based agroforestry systems. We also highlight results from an improved grass–legume pasture technology, and outline some actions needed for development and adoption of sustainable agroforestry systems in forest margins of the region.

Entry Points for Agroforestry Systems in Forest Margins

Two contrasting livestock-based systems are commonly found in the humid forest of tropical America, namely medium to large livestock operations and smallholder mixed farms. Each system has unique characteristics and consequently offers different opportunities to establish improved agroforestry practices.

Livestock systems

Large and medium-scale livestock operations in the humid forest of tropical America have been mainly formed by mechanised clearing of the forest. This is followed by the establishment of pastures for extensive beef production in less densely populated areas, or more intensive milk and beef production (i.e. dual purpose cattle systems) in areas with more population and market opportunities (Toledo and Torres 1990; Serrao and Dias Filho 1991).

These systems are not sustainable: introduced grasses, e.g. star grass, guinea grass, are not adapted to low soil fertility; there are biotic pressures on introduced grasses, e.g. spittlebug on *Brachiaria decumbens, B. humidicola*; and management practices are inadequate, e.g. the lack of fertilisation and overgrazing (Toledo 1985; Pezo et al. 1992). Thus, there is a need to reclaim large areas of degraded pastures through technologies that are ecologically sustainable and economically attractive to farmers.

Smallholder mixed systems

In smallholder colonist systems, clearing and burning of primary and secondary forest is followed by a sequence of annual crops, e.g. corn, beans, cassava, and the establishment of grass-based pastures. Within the farming system, cattle raising represents a form of income and savings with low opportunity cost in labour (Loker 1989; Kass et al. 1992). When pastures degrade due to reduced soil fertility and weed invasion, smallholders that are not constrained by land allow degraded areas to fallow. Thus, practices that shorten fallow periods could be attractive to these smallholders and also contribute to reduced pressure on the primary forest. However, there are smallholders that cannot fallow degraded areas due to limited land, particularly in Central America. Under these circumstances some agroforestry options are alley cropping (Kass et al. 1993b), and integration of leguminous trees in grazed pastures or cut and carry systems (Pezo et al. 1990).

Agroforestry Systems in the Region

In this section we briefly refer to livestock-based agroforestry systems practiced by some large- and smallholders in the humid forest areas of tropical America. In addition, we refer to agroforestry systems being researched and to systems that have been proposed to shorten fallow periods.

Examples of livestock-based agroforestry systems

There are two well documented examples of commercial livestock-based agroforestry systems in the humid forest of Central America. In Turrialba, Costa Rica, a system with *Pinus caribaea* for pulp and *Panicum maximum* as the dominant understorey was described by Somarriba and Lega (1991). Grazing of the understorey began when the plantation was 2.5 years old and ended when the trees were 8.5 years old, due to shading of the grass. The maximum stocking rate estimated for the system was 0.87 au/ha with a liveweight gain of 450 g/hd/day. The use of livestock in the system allowed extra income to the farmer and reduced cost of weeding and risk of fire. Another example of a livestock-based agroforestry in Turrialba, Costa Rica, involves the association of the grass *Axonopus compressus* with naturally generated trees of *Psidium guayaba* (average of 264 trees/ha). The trees provide fuelwood (4.3 m^3/ha) and fruits for livestock (11 kg/hd/day). The livestock also help to distribute the seed of the fruit in the pasture (Somarriba 1985 a, b, c).

Legume trees such as *Gliricidia sepium* and *Erythrina* spp. are also used by farmers in the humid forest of Central America as live fences or for shade in coffee plantations (Budowski 1987). However, their use for feeding livestock is limited—probably due to lack of dry season stress and high labour input needed in cut-and-carry systems.

In the forest margins of the eastern Brazilian Amazon, there are examples of agroforestry systems (Veiga and Serrao 1990). In these systems innovative farmers have planted trees, e.g. rubber, coconut palm, pine, mangoes, and Brazil nut, in degraded pasture areas using different spacing arrangements and grasses planted between rows for grazing. Success has been variable depending on the species of tree used and management applied. For example, stable and productive systems were observed with pine and

Brazil nut. In contrast, systems with Urucu (*Bixa orellana*) and coconut palm were considered to be less successful. Major limitations of the silvopastoral systems evaluated were damage to young trees by livestock and lack of persistence of the understorey pastures due to shading, overgrazing, lack of maintenance fertilisation and weed invasion (Veiga and Serrao 1990).

There are other examples of agroforestry systems used by smallholders in the Amazon basin. A system based on cashew nut is practiced in a farm community near Paragominas, Brazil (J. M. Spain, pers. comm.). After clearing and burning primary forest, seedlings of cashew nut (*Anacordium occidentalis*) are planted with an annual crop. At the end of the crop sequence, cashew nuts are 2–3 m tall and spaces between trees are planted with a grass, such as *B. decumbens*. Cattle consume the cashew apples and leave the nuts, which are gathered from the soil and the tree, untouched. The grass between rows of cashew trees in young plantations was vigorous and farmers indicated that it was more productive than in open pastures, until shaded-out.

Another form of agroforestry practiced by some smallholders in tropical America, involves the protection of valuable trees. In certain regions of the humid forest of Central America, farmers have come to appreciate the natural regeneration of *Cordia alliadora* in pastures. The timber has a high commercial value, and its straight trunk allows light penetration for pasture growth (Budowski 1993). In Acre, Brazil, some farmers protect the Brazil nut when clearing areas to establish crops and pastures (Toledo and Torres 1990). Also farmers in central and northern Brazil use the Babassu palm (*Orbignya martiana*), which dominates cleared sites and serves as a source fuel for burning to increase soil fertility, while allowing cropping or grazing between the trees (May et al. 1984).

Research on livestock-based agroforestry systems

In the humid tropics of Latin America two groups have been prominent in livestock-based agroforestry research: CATIE in Turrialba, Costa Rica, and CPATU/EMBRAPA in Belém, Brazil. Researchers at CATIE have evaluated nitrogen-fixing trees, such as *Erythrina* spp. and *Gliricidia sepium*, to recover degraded pastures (Romero et al. 1991) and to recycle nutrients (Libreros 1990; Cooperband 1992). Results have shown that biomass production and protein content of the widespread African star grass were higher when grown under *E. poeppigiana* than when grown alone (Pezo et al. 1990). Pastures under *E. poeppigiana* also reduced the invasion of weeds.

The group at CATIE also evaluated biomass production of different legumes and grasses grown in association with trees (Bazill 1987; Bustamante 1991), antinutritional factors in fodder from legume trees (Valerio 1990; Payne 1993) and the value of this fodder as a protein supplement for ruminants. For example, supplementation of *E. poeppigiana* resulted in linear increases in the milk yield of goats (Esnaola and Rios 1986) and cows (Tobón 1988) on grass basal diets. The work on feeding value of leguminous trees has been reviewed by Pezo et al. (1990), Romero et al. (1993) and Camero et al. (1993).

In Brazil, CPATU is well known for its work on pasture research, plant succession in abandoned pastures and testing of agroforestry systems for regeneration of degraded pastures. For example, researchers have been evaluating, in the Paragominas area, different tree species (i.e. *Schyzolobium amazonicum, Bagassa guianensis, Eucalyptus tereticornis*) in association with grasses, such as *B. brizantha* cv. Marandú, *B. humidicola*, and Coloniao. Results after 4 years (summarised by Veiga and Serrao 1990) showed that biomass yield under trees was more affected by the species of grass used than by the tree species. The grass *B. brizantha* cv. Marandú produced 2–2.5 times more dry matter than Coloniao, regardless of the tree species in the association. Work at CPATU has also shown that seedlings of certain tree species of economic value such as cashew nut (*A. occidentalis*), urucu (*B. orellana*) and mahogony (*Switenia macrophylla*) can be established successfully in degraded pastures. In addition, it has been shown that 70% of the cost of establishing trees in degraded pastures can be recovered by annual crops for 3 years.

Agroforestry research aimed at recuperating degraded pastures in the humid forest has also been carried out in the Amazon of Peru. Reátegui and Del Castillo (1990), successfully established pastures of *B. decumbens* in association with *Cedrelinga catenaeformis*, a native tree legume, using cassava as a pioneer crop. In the Amazon piedmont of Colombia, Florencia, Caquetá, where large areas of forest have been converted into pastures, a group of researchers of CORPOICA is currently multiplying and evaluating legume shrubs and trees, such as *Codariocalyx gyroides, Cratylia argentea, Gliricidia sepium, Clitoria fairchildiana,* and *Erythrina fusca* for the reclamation of degraded areas.

Of interest also is the 'coca' agroforestry research and development project carried out (1985–90) in smallholder farms in the lower forest of northeast Ecuador. The production system of colonists in the region is characterised by an area of robusta coffee producing 84% of income, cattle on pastures producing 11% of income and shifting cultivation of annual crops for home consumption on farms of 50 ha (Ramírez et al. 1992). The aim of the project was to: (1) increase or incorporate trees of commercial value into coffee and pasture areas; (2) improve management of coffee plantations; and (3) introduce a legume (*Desmodium ovalifolium*) as a cover crop in coffee, and in pastures in association with grasses (Peck and Bishop 1992).

Farmers in the project accepted natural regeneration or introduction of trees with commercial value in coffee and pastures. However, they were less enthusiastic about the use of *D. ovalifolium* as a cover in coffee or in association with grasses in pastures, mainly due to its aggressiveness and lack of palatability to cattle (Ramírez et al. 1992). Given that expansion of pastures for livestock was a high priority of farmers, it was recommended that future research emphasise development of high quality, productive, and persistent grass–legume pastures.

Research on fallow improvement

A common feature of traditional fallow systems practiced by indigenous communities in Central America and the Amazon basin is that trees with certain value are left standing when the forest is cleared for the cropping phase (Peck 1983; Kass et al. 1993a). As a result, the subsequent fallow is shorter due to increased biomass. Researchers have tried to mimic traditional fallow systems by introducing single tree species, usually nitrogen-fixing leguminous species. For example, the associations of *Inga edulis* with *D. ovalifolium* was found to be effective in reducing fallow periods in Yurimaguas, Peru (Szott et al. 1991). This same association was evaluated earlier in a humid forest site of Ecuador to enrich fallow in a system involving sheep (Bishop 1983). The Inga trees provided excellent fuelwood and charcoal in less than 6 years and *D. ovalifolium* provided forage for grazing sheep.

An agroforestry model to reduce fallow periods for mixed farming systems in forest margins was proposed by Loker (1989) after studying traditional slash-and-burn systems in Peru. The system defined as 1 year crop, 6 year pasture + trees and 2 year fallow has a number of advantages in mixed smallholder farms: sustained crop and livestock yield without application of purchased inputs; and reduced fallow period, which in turn could take pressure away from the primary forest. In addition, the system could be attractive to farmers since it attempts to maximise return to labour while minimising capital inputs. The key to viability of the model proposed by Loker (1989) is the natural regeneration of trees and the use of productive grass–legume pastures.

In general, the experience of some innovative farmers and results from research on agroforestry in the region has shown that natural regeneration or introduction of trees in pastures is feasible and that legume trees are an alternative to reduce fallow periods. In addition, research in the region has shown that trees in pastures contribute to nutrient cycling and to increased growth and protein content of certain grasses grown in the understorey. However, research has failed to show benefits of the tree component in animal production from grazed pastures.

Opportunities to Promote Livestock-based Agroforesty Systems

We acknowledge that technical solutions alone will not stop deforestation in the humid forest of tropical America. However, a discussion of nontechnical issues (i.e. policies) are beyond the scope of this paper and have been covered in a recent publication by Hecht (1993). In the discussion that follows we briefly refer to an improved grass–legume technology which has potential not only for reclaiming degraded areas, but also for preventing degradation in already deforested areas in tropical America.

Improved grass–legume technology

Pasture degradation in tropical forest margins begins with a decline in soil nutrients, followed by loss of plant vigour, weed invasion and soil compaction (Serrao and Toledo 1990). This process is particularly severe in pastures established with grasses poorly adapted to acid-infertile soils or the biotic environment. As a consequence, the TFP (Tropical Forages Program) of CIAT (Centro Internacional de Agricultura Tropical) and national research institutions of the region gave high priority to the development of a pasture technology which integrated acid-tolerant grasses with legumes to increase livestock production while preserving or enhancing soil fertility (Toledo 1985).

This effort has resulted in the selection of grass and legume species which allow high animal performance and pasture stability over time. For example, in Yurimaguas, Perú, grass–legume pastures (*Andropogon gayanus, Stylosanthes guianensis, Centrosema pubescens*) yielded annual liveweight gains of 400–500 kg/ha over a 10-year period (Lara et al. 1991). In the humid forest of Costa Rica (Guápiles), the association of *Brachiaria brizantha* cv. Diamantes (a grass resistant to spittlebug) with *Arachis pintoi* (forage peanut) has produced an average liveweight gain of 900 kg/ha/year over a 3-year period, which represents 30% more than obtained in the grass-alone pasture (Hernández, pers. comm.). In another humid forest region of Costa Rica (Turrialba), the association of star grass with *A. pintoi* resulted in 1 L/day more milk when compared to grass alone (Heurck 1990). These differences in liveweight gain and milk yield due to the legume are expected to be greater as pure grass pastures become nitrogen deficient and are invaded by weeds.

The *A. pintoi*–grass associations tested in humid forest and savanna environments are outstanding in that the amount of legume increases with increasing grazing pressure and the association resists weed invasion (Ibrahim et al. 1993; Lascano 1994). Grass–legume pastures grown in acid infertile soils were also shown to increase soil nitrogen in the savanna (Rao et al. 1994) and soil macrofauna biomass in the humid forest (Lavelle and Pashanasi 1989). A recent finding is that grass–legume pasture such as *B. humidicola/A. pintoi,* grown in heavy textured soils in savanna with high rainfall, accumulate 30% more organic carbon at depth in the soil compared to native grasses (Fisher, pers. comm.).

Therefore, these grass–legume pastures have great potential to increase livestock production, while contributing to reversing the degradation process in acid-infertile soils of forest margins and to carbon sequestration, which could have important environmental implications.

Integration of improved pastures and trees in livestock-based systems

Introduction of improved grass–legume pastures after slash-and-burn of secondary vegetation is an alternative that has been successful in smallholder farms in forest margins of Pucallpa, Peru (Loker 1988). However, recovery of native vegetation after abandonment of degraded pastures will depend on the intensity with which sites were used (Neptad et al. 1990). In severely degraded areas, where natural regeneration of forest vegetation is unlikely to occur, pasture establishment can be an expensive operation involving mechanisation, application of fertilizers and weed control. One possibility to reduce cost is through the establishment of the improved grass–legume pastures in association with annual crops, using acid-soil tolerant, new lines of rice developed by CIAT and used successfully in savannas of tropical America (Zeigler et al. 1994), and maize lines being developed by CYMMYT. Pasture renovation in better soils of the humid forest of Central America could also be accomplished through the association of improved grasses with maize or soybeans (Duarte 1991; Pérez et al. 1993). Alternatively, severely degraded areas could be renovated with acid-tolerant fast growing herbaceous legumes (i.e. *S. guianensis* cv. Pucallpa, *C. macrocarpum, Vigna ungiculata*) in a green-manuring system.

Planting trees in pastures is another alternative to reclaim degraded areas, even though some have expressed doubts on the willingness of farmers to engage in this activity, at least in the Amazon basin (Neptad et al., 1990). It is more likely to expect farmers to integrate trees into current production systems by protecting valuable tree species (i.e. timber, fuelwood, fruit) and/or by planting legume tree species as living fences or as a source of fodder, particularly in areas with a well defined dry season.

Actions Needed to Promote Adoption of Agroforestry Practices

Most of the literature available on systems that integrate trees, pastures and livestock is highly descriptive and inadequate to promote farmer adoption of new practices. Thus, there is a need to carry out participatory research. The onfarm research approach used in the 'coca' agroforestry project in Ecuador is in the right direction, and should be used as a model when designing new projects. However, onfarm research and development in agroforestry should be linked to seed supply systems for effective delivery to farmers of components being developed (i.e. tree, grass and legume species).

Finally, we acknowledge that livestock-based agroforestry systems are complex and of a long-term nature, and thus, pose serious difficulties for research. This complexity calls for an interdisciplinary approach to quantify processes and outputs in existing and new livestock-based agroforestry systems in the region.

Research priorities

After reviewing the literature on livestock-based agroforestry systems in the region, there are some areas that we feel merit immediate attention by researchers:

- Evaluation of indigenous and introduced tree species for performance in contrasting environments.
- Evaluation of acid-tolerant grass and legume germplasm for adaptation to soil, climate, pest and disease, and for ability to compete with weeds under different shade regimes.
- Methods of establishing grass–legume pastures, in combination with trees and annual crops, in deforested sites representing different stages of land degradation.
- Studies on animal production in grass and grass–legume pastures with and without trees.
- Studies on soil physical, chemical and biological changes in grass and grass–legume pastures with and without trees.
- Biological and economical assessment of performance of existing and new livestock-based agroforestry systems.

Conclusions

In this paper we have suggested the potential benefits of new productive and persistent grass–legume pastures as components of sustainable livestock-based agroforestry systems designed to reclaim degraded areas and prevent land degradation in forest margins of tropical America. However, we are not certain of the value of the forestry component since there is a lack of hard data on animal production amenable to analysis.

The improved grass–legume technology that is available to, and being adopted by, farmers, coupled with appropriate policies, could contribute to gradual conversion of what are now unstable and extractive production systems to stable and productive mixed systems. To accomplish this, there is a need to evaluate this pasture technology in areas of active colonisation, with and without a forestry component and using participatory research methods. If we fail to do so, our research and development efforts will not gain credibility among the farmer, government and donor community.

References

Anderson, A.B. 1990. Alternatives to deforestation: Steps towards sustainable use of the Amazon rain forest. New York, Columbia University Press.

Bazill, J.A.E. 1987. Evaluation of tropical forage legumes under *Pinus caribaea* var. Hondurensis in Turrialba, Costa Rica. Agroforestry Systems, 5, 97–108.

Bishop, J.P. 1983. Tropical forest sheep on legume forage/fuelwood fallows. Agroforestry Systems, 1, 79–84.

Budowski, G. 1987. Living fences, a wide agroforestry practice in Central America. In: Gholz, H.L., ed., Agroforestry: Realities, possibilities and potentials. Martinus Neijhoff Publishers, Dordrecht, The Netherlands, 169–178.

— 1993. The scope and potential of agroforestry in Central America. Agroforestry Systems, 23, 121–131.

Bustamante, J. 1991. Evaluación del comportamiento de ocho gramíneas forrajeras asociadas con poró (*Erythrina poeppigiana*) y solas. MS Tesis, CATIE, Turrialba, Costa Rica, 131 pp.

Camero, A., Vásquez, R., Alagón, G., Kass, M. and Romero, F. 1993. Uso de *Erythrina poeppigiana* como suplemento de forrajes con bajo contenido protéico. In: Westley, S.B., and Powell, M.H., ed., *Erythrina* in the new and old worlds. Nitrogen Fixing Tree Research Reports, Special Issue, Paia, Hawaii, 231–236.

Cooperband, L.R. 1992. Phosphorus dynamics in a humid tropical silvopastoral system. PhD Dissertation, Ohio State University, Columbus, Ohio, 400 pp.

Duarte, J.M. 1991. Efecto de los cultivos de maíz (*Zea mays* L.) o Vigna (*Vigna ungiculata* [L.] Walp) sobre el crecimiento de tres gramíneas forrajeras cuando se establecen en asocio. MS Thesis, CATIE, Turrialba, Costa Rica, 121 pp.

Esnaola, M.A. and Rios, C. 1986. Hojas de poró (*Erythrina poeppigiana*) como suplemento protéico para cabras lactantes. In: Resumen de las investigaciones realizadas con rumiantes menores en sistema de producción animal. CATIE, Turrialba, Costa Rica. Informe Técnico No. 6, 60–69.

Gutteridge, R.C. and Shelton, H.M. 1993. The scope and potential of tree legumes in agroforestry. Agroforestry Systems, 23, 177–194.

Hecht, S.B. 1985. Environment, development and politics: Capital accummulations and the livestock sector in Eastern Amazonia. World Development, 13, 663–684.

— 1993. The logic of livestock and deforestation in Amazonia. Bio Science, 43, 687–695.

Heurck, L.M. van. 1990. Evaluación del pasto estrella (*Cynodon nlemfuensis*) solo y asociado con las leguminosas forrajeras *Arachis pintoi* CIAT 17434 y *Desmodium ovalifolium* CIAT 350 en la producción de leche y sus componentes. MS Thesis. CATIE, Turrialba, Costa Rica, 111 pp.

Ibrahim, M., Mannetje L.'t and Pezo, D.A. 1993. Grass–legume balance under grazing in the humid tropics of Costa Rica. In Proceedings of the XVII International Grasslands Congress, Palmerston North, New Zealand and Rockhampton, Australia, 1934–1935.

Kass, D.L., Burgos, C. and Vargas, A. 1992. Sustainable land use systems research in Central America. In: International Workshop on Sustainable Land Use Systems Research. Proceedings, New Dehli, February 12–16, 1990, Oxford and IBH, 183–199.

Kass, D.C.L., Foletti, C., Szott, L.T., Landaverde, R. and Nolasco, R. 1993a. Traditional fallow systems of the Americas. Agroforestry Systems, 23, 207–218.

Kass, D.C.L., Jiménez, J., Sánchez, J., Soto, M.L. and Garzón, N. 1993b. *Erythrina* in alley farming. In: Westley, S.B. and Powell, M.H. ed, *Erythrina* in the new and old worlds. Nitrogen Fixing Tree Research Reports, Special Issue, Paia, Hawaii, 129–137.

Lara, D., Castilla, C. and Sánchez, P.A. 1991. Productividad y persistencia de pasturas asociadas bajo pastoreo en un ultisol de Yurimaguas. In: Smyth et al., ed., Manejo de suelos tropicales en Latinoamérica. NCSU, Soil Science Department, 86–89.

Lascano, C. 1994. Nutritive value and animal production of forage *Arachis*. In: Kerridge, P.C. and B. Hardy, B., ed., Biology and agronomy of forage *Arachis*. Centro Internacional de Agricultura Tropical (CIAT), 109–121.

Lavelle, P. and Pashanasi, B. 1989. Soil macrofauna and land management in Peruvian amazonian (Yurimaguas, Loreto), Pedobiología, 33, 283–291.

Leonard, M.J. 1987. Recursos naturales y desarrollo económico en América Central: un perfil ambiental regional. CATIE, Serie Técnica, Informe Técnico No. 127, CATIE, Turrialba, Costa Rica, 268 pp.

Libreros, H.F. 1990. Efecto de diferentes niveles de follaje de poró (*Erythrina poeppigiana*) en el suelo sobre la producción de king grass (*P. purpureum* × *P. typhoides*). MS Thesis, CATIE, Turrialba, Costa Rica, 84 pp.

Loker, W.W. 1988. Sustainability and pasture research in the humid tropics: A case study of the impact of public policy debates on international agriculture research. Paper presented at the Farming and Food Systems Symposium, Lima, Perú, CIAT, 37 pp.

— 1989. Why the cattle are eating the forest: farmer adaptive strategies and resource degradation in the humid tropics. Paper presented at the Animal Meeting of the American Anthropological Association, Washington, D.C.

May, P.H., Anderson, A.B., Balick, M.J. and Frazao, J.M.F. 1984. Subsistence benefits from the babassu palm (*Orbignya martiana*). Economic Botany, 39, 113–129.

Myers, N. 1981. How Central America's forest became North America's hamburgers. AMBIO, 10, 1, 3–8.

Nair, P.K.R. 1987. Soil productivity under agroforestry. In: Gholz, H.L., ed., Agroforestry: Realities, possibilities and potentials. Dordrecht, The Netherlands, Martinues Nyhoff Publishers, 21–30.

Neptad, D., Uhl, C. and Serrao, E.A.M. 1990. Surmounting barriers to forest regeneration in abandoned highly degraded pastures: a case study from Paragominas, Pará, Brazil. In: Anderson, A.B., ed., Alternatives to deforestation: steps toward sustainable use of the Amazon rain forest. New York, Columbia University Press, 215–229.

Payne, L.D. 1993. Chemical constituents of *Erythrina*: historical perspectives and future prospects. In: Westley, S.B and Powell, M.H., ed., *Erythrina* in the new and old worlds. Nitrogen Fixing Tree Association, Special Issue, Paia, Hawaii, 314–321.

Peck, R.B. 1983. Traditional forestation strategies of local farmers in the tropics. In: Wiersum, K.F. ed., Strategies and designs for deforestation, reforestation and tree planting, Wageningen: Pudoc, 205–216.

Peck, R.B. and Bishop, J.P. 1992. Management of secondary tree species in agroforestry systems to improve production sustainability in Amazonian Ecuador. Agroforestry Systems, 17, 53–62.

Pérez, H.E., Pezo, D.A. and Arze, J. 1993. Crecimiento de *Brachiaria brizantha* y *Brachiaria dictyoneura* asociadas con soya (*Glycine max* L.). Pasturas Tropicales, 15, 2–9.

Pezo, D., Kass, M., Benavides, J., Romero, F. and Cháves, C. 1990. Potential of legume tree fodders as animal feed in Central America. In: Davendra, C., ed., Shrubs and tree fodders for farm animals. Proceedings of a Workshop in Denpasar, Indonesia, 24–29 July 1989, Ottawa, Ontario, IDRC, 163–175.

Pezo, D.A., Romero, F. and Ibrahim, M. 1992. Producción, manejo y utilización de los pastos tropicales para la producción de leche y carne. In: Fernández-Boca, ed., Avances en la producción de leche y carne en el trópico americano. FAO, Santiago, Chile, 47–98.

Ramírez, A., Seré, C. and Uquillas, J. 1992. An economic analysis of improved agroforestry practices in the Amazon lowlands of Ecuador. Agroforestry Systems, 17, 65–82.

Rao, I.M., Ayarza, M.A. and Thomas, R.J. 1994. The use of carbon isotope ratios to evaluate legume contribution to soil enhancement in tropical pastures. Plant and Soil, in press.

Reátegui, K.J. and Del Castillo, D. 1990. Recuperación de laderas degradadas mediante sistemas agrosilvo-pastoriles. In: Keller-Grein, G., ed., Memorias de la Reunión de la Red Internacional de Evaluación de Pasturas Tropicales, RIEPT-Amazonía, Lima, Perú, 1990. CIAT, Documento de Trabajo No. 75, Vol. 2, 1061–1065.

Romero, F., Abarca, S., Corado, L., Tobón, J., Kass, M. and Pezo, D. 1993. Producción de leche de vacas en pastoreo suplementadas con poró (*Erythrina poeppigiana*) en el trópico húmedo de Costa Rica. In: Westley, S.B. and Powell, M.H., ed., *Erythrina* in the new and old worlds. Nitrogen Fixing Tree Research Reports, Special Issue, Paia, Hawaii, 223–230.

Romero, F., Camero, L.A., Montenegro, J. and Chana, C. 1991. Proyecto Sistemas silvopastoriles, Costa Rica. In: Ruiz. A. and Ruiz, M.E., ed., Red de Investigación en sistemas de producción animal de América Latina Memorias IX Reunión General, Zacatecas, México, 18–26 abril 1990. IICA, San José, Costa Rica, 135–162.

Serrao, E.A.S. and Toledo, J.M. 1990. The search for sustainability in Amazonian pastures. In: Anderson, A.B., ed., Alternatives to deforestation: steps toward sustainable use of the Amazon rain forest. New York, Columbia University Press, 195–214.

Serrao, E.A.S. and Dias Filho, M.B. 1991. Establecimiento y recuperación de pasturas entre los productores del trópico húmero brasileño. In: Lascano, C. and Spain, J.M., ed., Establecimiento y renovación de pasturas: conceptos, experiencias y enfoque de investigación. CIAT, 347–383.

Somarriba, E. 1985a. Arboles de guayaba (*Psidium guayaba* L.) en pastizales. 1. Producción de fruta y potencial de dispersión de semillas. Turrialba 35, 289–295.

— 1985b. Arboles de guayaba (*Psidium guayaba* L.) en pastizales. 2. Consumo de fruta y dispersión de semillas, Turrialba, 35, 329–332.

— 1985c. Arboles de guayaba (*Psidium guayaba* L.) en pastizales. 3. Producción de leña. Turrialba, 35, 333–338.

Somarriba, E. and Lega, F. 1991. Cattle grazing under *Pinus caribeae*. 1. Evaluation of farm historical data on stand age and animal stocking rate. Agroforestry Systems, 13, 177–185.

Szott, L.T., Palm, C.A. and Sánchez, P.A. 1991. Agroforestry on acid soils of the humid tropics. Advances in Agronomy, 45, 275–300.

Tobón, C.J. 1988. Efecto de la suplemnetación con cuatro niveles de follaje de poró (*Erythrina poeppigiana*) sobre la producción de leche en vacas en pastoreo. MS Thesis, CATIE, Turrialba, Costa Rica, 72 p.

Toledo, J.M. 1985. Pasture development for cattle production in the major ecosystems of the tropical American lowlands. In: Proceedings of the XV International Grasslands Congress, Kyoto, Japan, 74–78.

Toledo, J.M. and Torres, F. 1990. Potential of silvo-pastoral systems in the rain forest. In: Moore, I., ed., Agroforestry Land-Use Systems, Nitrogen Fixing Tree Association, Paia, Hawaii, 35–52.

Valerio, S. 1990. Efecto del secado y del método de análisis sobre los estimados de taninos y la relación de éstos con la digestibilidad in vitro de algunos forrajes tropicales. MS Thesis, CATIE-Turrialba, Costa Rica, 94 pp.

Veiga, J.B. and Serrao, E.A.S. 1990. Sistemas silvopastoris e producao animal nos tropicos umidos: A experience da Amazonia brasilera. In: Pastagens/Sociedade Brasileira de Zootecnia, FEALQ, Piracicaba, SP, 37–68.

Vergara, N.T. 1987. Agroforestry: A sustainable land use for fragile ecosystems in the humid tropics. In: Gholz, H.L., ed., Agroforestry: realities, possibilities and potentials. Dordrecht, The Netherlands, Martinus Nijhoff Publishers, 7–19.

Ziegler, R.S., Sanz, J.I. and Toledo, J.M. 1994. Developing sustainable agricultural systems for the acid savannas of Latin America. In: International Symposium on Agroecology and Conservation in Temperate and Tropical Regions. September, 26–29, 1991, Padoria, Italy, in press.

Agroforestry Systems in Africa: Role in Livestock Production and Protection of the Environment

B.H. Dzowela* and M.A. Saleem†

Abstract

Agroforestry practices and systems for supporting pastoral and agropastoral livestock production in Africa range from the preservation of trees to more intensively planted and managed systems. In the extensive traditional practice of tree conservation, use strategy is geared towards biomass maintenance rather than production. Certain native tree species are protected for their fodder value in grazing and crop lands. A mixture of livestock, grazers and browsers make the best use of vegetation types and forms.

In intensively managed agroforestry systems of mixed crop–livestock production, leguminous multipurpose trees are planted as fodder banks, alley-farmed or planted as contour-bund hedges. Plantation crop understoreys are planted to aid nutrient cycling and provide high quality supplemental fodders. These agroforestry systems provide potential for environmental protection in sustaining watershed effects of the remaining tropical woodlands. These systems prevent overgrazing by encouraging intensively managed livestock production in zero-grazing systems; arrest deforestation; create a carbon sink through afforestation; reduce soil and water erosion; and sustain the very basis of agricultural productivity for both the crop and livestock subsectors.

DEFORESTATION and soil degradation have increased in most African countries since the 1970s when they were first noted (Thompson 1992; Van den Beldt 1994). Deteriorating soil resources, degradation of watershed and fresh water resources, and the overgrazing of rangelands by ruminant livestock affect whole human populations and the future of ruminant livestock production.

The emergence of global awareness about development issues must be matched by innovative approaches to deforestation. Agroforestry is showing potential as a sustainable landuse option in African agricultural systems. In this regard, the development of sustainable grazing and fodder resource-use systems is vital. Resource-poor, mixed crop–livestock production systems will increasingly depend on the N-input from biological N-fixation by tree and shrub legumes.

* International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya.

† International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

This paper looks at agroforestry options available to mixed crop–livestock smallholder farmers, especially with respect to sustaining crop yields and livestock production through animal traction for ploughing and the provision of manure. The paper also addresses issues of protecting the environment within the context of pastoralism and agropastoralism.

Agroforestry in Traditional Pastoralist Systems

Silvopastoral systems in Africa have strategies for managing natural resources. In arid and semi-arid areas such systems aim to mitigate against the vagaries of climate and the harshness of the land (Barrow 1991). For instance, among the Ngisanyoka people in the South Turkana region of northern Kenya, pastoral land use is orientated towards biomass maintenance rather than production and there is no evidence of deforestation or other environmental misuse. Livestock take advantage of the existing woody forage, and because of their mobility, exploitation is dispersed. This encourages selective use of trees and contributes to their conservation. Flexibility in user rights and mobility of livestock grazing and herding in space and time is a strategy to reduce environmentally-derived risks (Storas 1987). A mixture of livestock species (grazers and browsers) makes the best use of the different forms of vegetation (woody species, herbs and grasses) (Barrow 1991). Important tree species (e.g. *Acacia tortilis, Hyphaena compressa, Cordia sinensis, Zizyphus mauritiana, Dobera glabra* and *Faidherbia albida*) are protected by custom or managed for economic benefits, as in the Sahel (Weber and Hoskins 1983). In the southern and northern Guinea zone of West Africa, trees such as *Parkia* spp., *Vitex doniana, Daniellia oliveri, Afzelia africana, Faidherbia albida, Adansonia digitata, Tamarindus indica* and *Balanites aegyptica* are protected in croplands largely for their nutritious seeds and pods which are used for livestock fodder and human food during the dry seasons (Ichire 1993).

Agroforestry in Extensive Agropastoral Systems

Livestock are a valuable component of most smallholder farming systems. They provide the traction to plough fields, manure to sustain crop productivity and nutritious food products such as meat and milk. In agropastoral mixed crop–livestock systems of the southern African subregion, traditional agroforestry practices take the form of planting of mainly exotic trees around homesteads and in garden plots in Zimbabwe (Gumbo et al. 1989; Campbell et al. 1991). Conservation of selected indigenous trees in the main arable lands and to some extent in grazing areas is another practice. This is known as the parkland agroforestry system.

Trees are important for their fruits and shade and to some extent their social value. For instance, large *Parinari curatellifolia* trees are often used as meeting places (Campbell et al. 1991). Other trees have important medicinal and spiritual value, for instance *Lonchocarpus capassa, Kigelia africana* and *Pseudolanchnostylis maprouneifolia*. Some trees are left because they are difficult to fell. Other trees are valued for their browse potential (Scoones and Madyakuseni 1987).

Trees in grazing areas provide litter for composting of gardens or for bulking up manure (Swift et al. 1989; Nyathi and Campbell 1993). In addition, many of the dominant species in the grazing areas provide good quality browse. For instance, *Julbernadia globiflora, Combretum apiculatum, Colophospermum mopane, Lonchorcarpus capassa, Piliostigma thonningii* and *Terminalia sericea* supply a large proportion of the protein intake of livestock especially during the critical late dry season, when there is little grass and herbaceous plants are desiccated.

Grazing in the shade of trees protects livestock from wind and direct sunlight. Livestock under shade spend less energy to regulate body temperature, thus allowing animals to store more energy for subsequent work and production. While standing in the shade, animals deposit dung which benefits the trees.

Agroforestry in Intensive Agropastoral Systems

Leguminous trees and shrubs in intensively managed mixed crop–livestock farming systems can enhance the recycling of nutrients; fix nitrogen and lower soil temperature; reduce soil evaporation; minimise leaching and runoff; and in some cases supply human food (Dzowela 1993). The role of trees and shrubs varies in different forms of agroforestry (Tothill 1986; Torres 1983). For instance, in southeastern Nigeria, which is dominated by acidic soils, agriculture is predominantly based on bush fallow–food crop rotation systems. However, the fallow periods have been reduced drastically in recent times, forcing some farmers to deliberately plant selected bushes such as *Acioa barteri, Alchornea cordifolia* and *Dialium guineense* (Cobbina et al. 1990).

In southern Africa, the feed supply problem is pronounced in the dry season when grasses and other herbaceous vegetation are dried up and of poor quality. Livestock are forced to eat poor quality roughages, such as natural pastures and crop residues, often with no commercial proteinaceous supplements. There are three problems associated with using these poor quality feeds: they are often unavailable on account of high costs; intake by livestock and nutritive value in terms of crude protein are low; and mineral contents (phosphorus) and vitamins are low. The low feed intake by the livestock leads to poor performance. There is thus a need (exacerbated by the increasing grazing pressure on lands caused by increasing human population) for intensifying livestock production in east and southern Africa. For example, in Zimbabwe, it is estimated that during the period 1970 to 1978, the human population increased by 50%; the cattle population increased by 22%; while the area of cultivated land also increased by 55%, so reducing the area of pastures. During the same period the area available to grazing declined by 15%. These changes resulted in grazing area per head of cattle falling from 2.5 ha/hd to 1.7 ha/hd. This situation suggests that the overgrazing problem will worsen, as both cattle and human populations continue to increase (Zimbabwe, Ministry of Internal Affairs 1979).

Through the use of multipurpose leguminous fodder trees and shrubs that remain green during the dry season, the supplementation of poor quality native pastures and crop residues can be achieved (Torres

1983). High protein forage is possible by combining legume trees with a grass forage, primarily attributed to symbiotic nitrogen fixation (Table 1). If the dung, urine and reject forage from cut-and-carry intensive management systems are carefully collected and returned onto the pasture or degraded crop lands, nutrient cycling is aided and sustainable crop–livestock systems are ensured. Furthermore, since legume trees have deep-rooting systems, they can tap nutrients in low concentrations throughout the soil profile. By taking these nutrients up so that they become concentrated near the soil surface from litter fall and decomposition they increase the supply of nutrients to shallow-rooted companion grass or crop. It is on this basis that the improved tree fallow agroforestry system as advocated by ICRAF's Agroforestry Research Network in Africa (AFRENA) in the southern African 'Miombo' woodland plateau has been conceptualised.

In parts of eastern and central Africa, high biomass-producing Napier grass (*Pennisetum purpureum* Schumach) is the major feed for intensively managed stall-fed dairy and beef fattening livestock (Abate et al. 1993). Its protein content under farm conditions ranges from 7.4% to 16% (Ogwang and Mugerwa 1976). Napier grass yields onfarm range from 12 to 30 t dry matter (DM) per hectare with milk yields ranging between 6 and 9 kg/day for lactating cows (Van der Valk 1990; Bayer 1990). Kapinga and Shayo (1990) report that multipurpose leguminous trees are capable of producing 20 t DM/ha biomass. Introducing multipurpose leguminous trees such as *Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrsus* and to some extent *Sesbania sesban* in contour-bund hedges and alley cropping/farming systems (Abate et al. 1993) further increases quality herbage available per land unit. Where such interventions have been possible, animal performance and productivity are better and economical at farm level (Table 2).

Other examples of intensive systems come from the subhumid Kenyan and Tanzanian coastal region, where copra cake and leucaena leaf meal are used as home-grown supplements to Napier grass diets (Table 3).

As an agroforestry system, alley farming (Kang et al. 1990) and intensive feed gardens (Atta-Krah and Sumberg 1988) have been tested and proven to be viable in southwestern Nigeria using *Gliricidia sepium* and *Leucaena leucocephala*. Other nonleguminous trees are also showing potential for these systems (Larbi et al. 1993).

Plantation crops agroforestry

Cattle grazing under forestry plantations is a well documented production alternative in temperate and subtropical areas (Adams 1975; Tustin et al. 1979; Somarriba and Lega 1991). The aim in this system is to use the herbaceous understorey for fodder production. It is a biologically-feasible and economically-attractive integrated form of land use. However, in the tropics little information is available (Bell 1981). Where the system is practiced in limited areas, the adverse effects of the animal component have been observed through trampling, bark-striping, direct browsing or soil compaction.

In the coastal belt of Tanzania and Kenya cattle grazing under coconut–cashew tree plantations is a common feature (Thorpe et al. 1993). A variety of grasses grow under these plantations, predominant of which is *Panicum maximum* and to some extent *Cynodon nlemfuensis*. The existence of palm and cashew tree stands of variable ages, growing at different sites, has contributed to a mosaic of pastures mixed with various weed types. Attempts have been made to increase understorey productivity by including *Leu-*

Table 1. Potential for nitrogen yields (kg/ha) over a 14-month period of a legume tree–grass mixture (adapted from Blair et al. 1990).

	Tree monoculture	Tree–grass mixture	Grass monoculture
Leaf N yield	751	669	–
Stem N yield	150	132	–
Total legume N yield	901	801	–
Grass (%N)	–	1.3	0.9
Grass N yield	–	100	103
Total edible N yield	752	769	103
Total N yield	901	901	103

Table 2. Dry matter intake and milk production by grade cows fed fodder-based diets in intensive feeding systems (Abate et al. 1993).

Basal deal	Supplement	Total intake	Animal	Milk
Napier grass	No concentrate	13.9	Friesian	10.5
Napier grass	8 kg concentrate	18.9	Friesian	15.0
Napier grass	2 kg concentrate	11.6	crossbreds	7.1
Green maize	2 kg concentrate	12.0	crossbreds	8.1
Napier grass	No leucaena	7.8	crossbreds	7.2
Napier grass	4 kg leucaena	9.3	crossbreds	7.6
Napier grass	8 kg leucaena	10.4	crossbreds	8.3
Early cut Napier silage	2 kg concentrate	8.9	crossbreds	11.7
Early cut Napier silage	4 kg concentrate	8.7	crossbreds	12.3

caena leucocephala and a shrub legume, *Clitoria ternatea*, among the plantation crops. Grazing under plantation crops requires management expertise of both foresters and cattle ranchers. Reasonably high stocking rates (e.g. 0.5 to 0.6 au/ha/year) are possible on these systems.

Free grazing, tethering of animals, especially where there are arable crops such maize and/or cassava, or cutting and carrying the forage to livestock in feeding stalls are some management options under permanent plantation crops. The latter is common practice with smallholder dairy farmers in the coastal regions of Kenya (Mombasa) and Tanzania (Tanga).

Fodder on contour-bunds

In east Africa, fodder production in intensive mixed crop–livestock systems involves growing leguminous fodder trees/shrubs in combination with grasses on field contour-bunds. The main mixtures consist of tree legumes, such as *Calliandra calothyrsus*, *Leucaena* spp. (*L. leucocephala*, *L. diversifolia* and *L. pallida*), and to some extent *Mimosa scabbrella, Sesbania sesban* and *Cajanus cajan*. The grass species are mostly *Pennisetum purpureum* and *Setaria splendida* in pure stands or in mixed stands with *Desmodium intortum*.

It appears that *Pennisetum purpureum* alone can economically maintain a local Zebu cow as its productivity level is normally low. However, for high milk production, using improved breeds of cattle, farmers have to introduce fodder trees and shrubs for additional feed. The higher the milk production expected, the greater is the proportion of fodder trees and shrubs (pure or mixed with grass components) required per bund area (Hoekstra 1991).

Pennisetum purpureum, pure or in mixture, tends to compete with adjacent crops, and therefore may not be suitable for intercropping. Since maize is the staple crop in smallholder production systems of east and southern Africa, the stover is a readily available home-grown feed resource. Where land is scarce, farmers will have to increase feed from the same croplands. In this context, tropical browse species such as *Gliricidia sepium, Leucaena leucocephala, Sesbania sesban* or *Calliandra calothyrsus* potentially are useful for improving feed quality and quantity, and productivity of livestock at low cost.

In tree-focused agroforestry research in east Africa, a wide range of tree species (*Gmelina arborea, Leu-*

Table 3. Effect of Napier fodder supplementation on dry matter intake, liveweight change and milk yield of lactating cows (adapted from Muinga et al. 1992).

Treatments	Napier intake (kg/day)	Total intake (kg/day)	Intake per 100 kg metabolic weight (kg)	Milk yield (kg)	Body weight (kg)
Napier fodder only	5.5	5.5	3.4	4.2	7.1
Napier + copra cake	5.6	6.8	2.9	5.2	6.1
Napier + leucaena	5.8	7.0	3.4	5.2	7.6

caena leucocephala, Faidherbia albida, Eucalyptus camaldulensis, Grevillea robusta, Calliandra calothyrsus and *Sesbania sesban*) are used as live stakes for climbing beans. Yield increases have been realised where beans are grown in association with these leguminous trees and shrubs (Graf and Ndorehayo n.d.) due to nutrients recycled through tree leaves applied as green manure. When the beans are harvested, the tree foliage provides additional fodder during the dry seasons.

Secondary compounds

Tree and shrub foliage contains secondary compounds, mostly proanthcyanidins and related flavonoids commonly known as polyphenolics and condensed tannins. These are anti-nutritional compounds which affect feed intake, nutrient digestion and absorption when fed to livestock (Van Hoven 1984; Reed 1986; Reed et al. 1990). These compounds affect nutrient cycling by slowing down decomposition of organic matter in soils, and therefore tree species for agroforestry systems need to be selected carefully if improving soil fertility and organic matter of degraded lands is a major objective (Palm and Sanchez 1991).

Common trees and shrubs that have these secondary compounds in agroforestry systems include *Acacia angustissima, Calliandra calothyrsus, Sesbania macrantha*, and also some of the lesser known species. They are known to alter the chemical and physical properties of manure from ruminant livestock that feed on leaves and fruits of such woody species (Woodward and Jess 1989; Reed et al. 1990; Somda et al. 1994). It is estimated that over 60% of the nitrogen from dietary protein is excreted in the urine when ruminant livestock are fed browse fodder which contains low levels of polyphenols and condensed tannins. However, urinary nitrogen is rapidly volatilised and lost from the soil. On the other hand, over 60% of the nitrogen is excreted in the faeces of ruminants fed on tree foliage which contains high levels of these compounds, thus slowing nitrogen mineralisation (J.D. Reed, pers. comm.). Anti-nutritional compounds also increase bulk density and decrease water-holding capacity of manure. All these changes in composition have practical implications for the use of manure in soil fertility and organic matter management in mixed crop–livestock intensive farming systems.

Agroforestry and Environmental Protection

In sub-Saharan Africa, agroforestry has a role to sustain land productivity for increasing human and livestock populations. It also provides an alternative for better use of waste and degraded lands. Judicious use of some of the multipurpose tree species includes home-grown firewood resources, thus avoiding the need for indiscriminate cutting of remaining woodlands. Deforestation in Africa needs to be arrested; otherwise, there is a risk of mass soil erosion, particularly on sloping land, threatening water courses and dams with siltation. Adoption of contour-bund plantings of trees and fodder tree (protein) banks in farmlands as a farming practice may help to check soil and water erosion.

As farmers resort to intensive mixed crop–livestock production systems, as is happening in the land-scarce east African region, free and communal grazing lands are encroached for cropping. Farmers are therefore forced to reduce livestock numbers, concentrating on premium stocks such as dairy cows, traction cattle, and sheep and goats which are managed in backyards by zero-grazing. It is in these systems that agroforestry-mediated leguminous tree species have the greatest potential as feed supplements for poor quality home-grown cereal crop residues. Intensive livestock production systems also favour the flow of nutrients between the crop and livestock subsectors. High quality manures and slurry from feeding pens and forage rejects returned to the crop lands contribute to sustained productivity, and reduce dependency on fertilizers. Of course, manure is a pollutant only when used in excess and this does not happen in Africa. Confining livestock in backyards reduces the chances for environmental mismanagement from overgrazing and soil trampling.

Afforestation mediated through agroforestry-defined niches (contour-bunds, alley farming, fodder banks on degraded and waste lands) are opportunities to create alternative sinks for excess atmospheric carbon (Dixon et al. 1994). This would have a farreaching environmental effect as the threat of global warming increases.

The chemical and biochemical components in the foliage of agroforestry multipurpose tree species also could have allelopathic effects on other plant species growing around them, resulting in localised reduction of plant biodiversity. In integrative agroforestry systems (alley farming for instance) allelopathic effects may be environmentally beneficial if weeds can be selectively controlled. Such effects need further investigation.

Conclusion

Traditional agroforestry pastoral and extensive agro-pastoral systems exist in Africa. They are geared towards raising productivity in livestock systems through the production of fodder from woody and herbaceous species as well as towards reducing environmental risks. These traditional systems encourage mobile and dispersed exploitation patterns, and conservative and selective use of trees. A mixture of livestock species which includes grazers and browsers makes the best use of different forms of vegetation. Tree species are therefore protected in both grazing and crop lands.

In more intensive mixed crop–livestock production systems, certain tree and shrub species are deliberately planted and managed as fodder/protein banks, plantation crop understoreys, and alley-farmed or contour-bund hedgerows. In these intensively managed agroforestry systems, leguminous multipurpose trees and bushes are used as home-grown high protein supplements to grass-based zero-grazing forages. In addition, they are used as supplements for poor quality natural pastures and cereal crop residues. Such systems also assist soil fertility restoration and provide high quality manures.

When widely applied, agroforestry systems in Africa have the potential for environmental protection through reduction of overgrazing, one of the major causes of land degradation. Agroforestry systems also encourage tree planting, thus creating carbon sinks, improving the hydrology of catchments, and reducing erosion and the siltation of water courses and dams.

Acknowledgments

Useful comments and suggestions received from Drs R.R.B. Leakey, Kwesi N. Atta-Krah and Ekow Akyeampong during preparation of this review paper are gratefully acknowledged.

References

Abate, A., Dzowela, B.H. and Kategile, J.A. 1993. Intensive animal feeding practices for optimum feed utilization. In: Kategile, J.A. and Mubi, S., ed., Proceedings of a workshop on future of livestock industries in east and southern Africa, 20–23 July 1992, Kadoma Ranch Hotel, Zimbabwe. Addis Ababa, Ethiopia, ILCA, 9–19.

Adams, S.N. 1975. Sheep and cattle grazing in forests. Journal of Applied Ecology, 12, 143–152.

Atta-Krah, A.N. and Sumberg, J.E. 1988. Studies with *Gliricidia sepium* for crop/livestock production systems in West Africa. Agroforestry Systems, 6, 97–118.

Barrow, E.G.C. 1991. Evaluating the effectiveness of participatory agroforestry extension programmes in a pastoral system; based on existing traditional values. A case study of the Turkan in Kenya. Agroforestry Systems, 14, 1–21.

Bayer, W. 1990. Napier grass — a promising fodder for smallholder livestock production in the tropics. Plant Research and Development, 31, 103–111.

Bell, T.I.W. 1981. Tree spacing and cattle grazing in young *Pinus caribaea* plantations in Fiji. Suva, Fiji, Forestry Department Fiji Pine Research Paper No. 9, 7 p.

Blair, G., Catchpoole, D. and Home, P. 1990. Forage tree legumes: their management and contribution to the nitrogen economy of wet and humid tropical environments. Advances in Agronomy, 44, 27–54.

Campbell, B.M., Clarke, J.M. and Gumbo, D.J. 1991. Traditional agroforestry practices in Zimbabwe. Agroforestry Systems, 14, 99–111.

Cobbina, J., Atta-Krah, A.N., Meregini, A.O. and Duguma, B. 1990. Productivity of some browse plants on acid soils of south-eastern Nigeria. Tropical Grasslands, 24, 41–45.

Dixon, R.K., Brown, S., Houghton, R.A., Solomon, A.M., Trexler, M.C. and Wisniewski, J. 1994. Carbon pools and flux of global forest ecosystems. Science, 263, 185–190.

Dzowela, B.H. 1993. Advances in forage legumes: a sub-sahara African perspective. Proceedings of the XVII International Grasslands Congress, 7–12 February 1993. Palmeston North, New Zealand and Rockhampton, Australia, in press.

Graf, W. and Ndorehayo, V. n.d. Agroforestry research in bean-based cropping systems. Systems of sub-Sahalian Africa: a review of research methodologies and results. Report of the Great Lakes Bean Program. Rwanda Institute of Agricultural Research.

Gumbo, D.J., Makamuri, B.B., Muzondo, M.I. and Scoones, I.C. 1989. Indigenous and exotic fruit trees: why do people want to grow them? In: Proceedings of the conference on the economics of agroforestry, Mbabane, Swaziland. London, Commonwealth Science Council.

Hoekstra, D.A. 1991. Economic evaluation of fodder production from grasses and shrubs grown on field bunds at Rwerere (unpublished mimeo), 7 p.

Ichire, O. 1993. Trees for food and fodder production in dryland Nigeria. Agroforestry Today, 5(1), 12–13.

Kang, B.T., Reynolds, L. and Atta-Krah, A.N. 1990. Alley farming, Advances in Agronomy, 43, 315–359.

Kapinga, P.E.X and Shayo, E. 1990. Forage production and utilization at small-scale holder level in Tanga district, Tanzania. In: Dzowela, B.H., Said, A.N., Wendem-Agenehu, A. and Kategile, J.A., ed., proceedings of PANESA/ARNAB joint workshop held in Lilongwe, Malawi, 5–9 December 1988. Addis Ababa, Ethiopia, ILCA, 140–156.

Larbi, A., Jabbar, M.A., Orok, E.J., Indiong, N.B. and Cobbina, J. 1993. *Alchornea cordifolia*, a promising indigenous browse species adapted to acid soils in south eastern Nigeria for integrated crop-livestock agroforestry production systems. Agroforestry Systems, 22, 33–41.

Muinga, R.W., Thorpe, W. and Topps, J.H. 1992. Voluntary feed intake, liveweight and lactation performance of crossbred dairy cows given *ad libitum Pennisetum purperum* (Napier grass cv. Bana) supplemented with *Leucaena* forage in the lowland semi-humid tropics. Animal Production, 55, 331–337.

Nyathi, P. and Campbell, B.M. 1993. The acquisition and use of miombo litter by small-scale farmers in Masvingo, Zimbabwe. Agroforestry Systems, 22, 43–48.

Ogwang, B.H. and Mugerwa, J.S. 1976. Yield response to nitrogen application and in vitro dry matter digestibility of elephant grass × bullrush millet hybrids. East African Agriculture and Forestry Journal, 41, 231–242.

Palm, C.A. and Sanchez, P.A. 1991. Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. Soil Biology and Biochemistry, 23, 83–88.

Reed, J.D. 1986. Relationships among soluble phenolics, insoluble proanthocyanidins and fibre in East African browse species. Journal of Range Management, 39, 5–7.

Reed, J.D., Soller, H. and Woodward, A. 1990. Fodder tree and straw diets for sheep: intake, growth, digestibility and effects of phenolics on nitrogen utilization. Animal Feed Science and Technology, 30, 39–50.

Scoones, I. and Madyakuseni, J. 1987. Local perspections of the contribution of trees to browse and their effects on grass production in Mazvihwa Communal Area, Zvishavane District, Zimbabwe, unpublished mimeo.

Somarriba, E. and Lega, F. 1991. Cattle grazing under *Pinus caribaea* 1. Evaluation of farm historical data on stand age and animal stocking rate. Agroforestry Systems, 13, 177–185.

Somda, Z.C., Powell, J.M., Fernadez-Rivora, S. and Reed, J.D. 1994. Feed factors affecting nutrient excretion by ruminants and fate of nutrients when applied to soil. In: Proceedings of the International Conference on Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa, 22–26 November 1993. Addis Ababa, Ethiopia, ILCA, in press.

Storas, F. 1987. Intention or implication — the effects of Turkana social organization on ecological balances. In: Baxter, P.T.W. and Hogg, R., ed., Property, poverty and people: changing rights in property and problems of pastoral development. Manchester University, U.K., Department of Social Anthropology and International Development Centre, 137–146.

Swift, M.J., Frost, P.G.H., Campbell, B.M., Hatton, J.C. and Wilson, K. 1989. Nutrient cycling in farming systems derived from Savanna: perspectives and challenges. In: Charholin, M. and Bergston, J., ed., Ecology of arable lands. The Hague, Kluwer, 63–76.

Thompson, T.R.E. 1992. An approach to the setting of environmental quality objectives for soil and land. Biologist, 39 (1), 33–34.

Thorpe, W.R., Mullins, G., Reynolds, L., Maloo, S.H., Muinga, R.W., Mureithi, J.G., Njuni, M. and Ramadhan, A. 1993. Research on smallholder dairy production in coastal lowland Kenya. In: Kategile, J.A. and Mubi, S., ed., Proceedings of a workshop on the future of livestock industries in east and southern Africa, 20–23 July 1992. Kadoma Ranch Hotel, Zimbabwe. ILCA, Addis Ababa, Ethiopia, 33–44.

Torres, F. 1983. Role of woody perennials in animal agroforestry. Agroforestry Systems, 1, 131–163.

Tothill, J.C. 1986. Application of agroforestry to African crop–livestock farming systems. Addis Ababa, ILCA, mimeo.

Tustin, J.R., Knowles, R.L. and Klomp, B.K. 1979. Forest farming: a multiple landuse production system in New Zealand. Forest Ecology and Management, 2, 169–189.

Van den Beldt, R.J. 1994. The future role of leguminous multipurpose trees in tropical farming systems. Proceedings on network for *Leucaena* Research and Development, 24–29 January 1994, Bogor, Indonesia. In press.

Van der Valk, Y.S. 1990. Review report of the DEAF-surveys during 1989. Naivasha, Kenya, National Dairy Development Project, Ministry of Livestock Development, 69 p.

Van Hoven, W. 1984. Tannins and digestibility in greater Kudu. Canadian Journal of Animal Science, 64 (suppt), 177–178.

Weber, F. and Hoskins, M. 1983. Agroforestry in the Sahel. A concept paper based on the Niamey Agroforestry Seminar, 23 May–9 June 1993. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, Department of Sociology, 102 p.

Woodward, A. and Jess, J.D. 1989. The influence of polyphenolics on the nutritive value of browse: a summary of research conducted at ILCA. ILCA Bulletin, 35, 2–11.

Zimbabwe, Ministry of Internal Affairs. 1979. Resource Survey No. 1: Murehwa–Mutoko–Mudzi. National Service Research Unit, Ministry of Internal Affairs, Harare, Zimbabwe.

Agroforestry in Asia and the Pacific: with Special Reference to Silvopasture Systems

A. N. Gintings* and C. K. Lai†

Abstract

Agroforestry as a farming system has been practiced in the Asia-Pacific region for many centuries. Agroforestry practices and systems are diverse and vary within and between countries.

Population growth is increasing the need for more agricultural land; at the same time the land available for agriculture is dwindling. Consequently, the pressure on forest and land resources is becoming serious. The development of an appropriate agroforestry system in all agroecological zones is necessary.

Silvopasture is one form of agroforestry that produces grasses/fodder for livestock. The examples of silvopasture systems in several countries in the Asia-Pacific region are described.

Future directions for agroforestry and silvopasture research and development are:

- Provision of information (research results, demonstration plots, extension, technical assistance etc.) to attract farmers to adopt agroforestry systems.
- Assistance to farmers so that a more equitable distribution of benefits from sustainable agroforestry on government lands is achieved.
- Provision of education and training for all officers so that they can promote agroforestry on private lands/uplands/forest lands and on government lands.

TRADITIONAL forms of agroforestry have been practiced, and have evolved, for many centuries throughout the world. Agroforestry practices and systems are diverse and vary within and between countries.

Over the centuries, farmers in the Asia–Pacific region have developed sustainable agroforestry systems that produce crops, trees, livestock, fish and related resources. More recently, agroforestry research, development and training activities have been promoted by government agencies, universities and training institutions, and nongovernment and local organisations. Agroforestry systems, both traditional and introduced, arguably find their greatest expression of diversity and relevance in the Asia–Pacific region, especially in the many densely populated areas found throughout south Asia and southeast Asia (Tejwani and Lai 1992).

In the region, the most appropriate and simple definition of agroforestry is the use of trees in farming systems. Farmers ingeniously combine the production of crops, trees, livestock, fish or other components.

For the sake of classification, agroforestry systems may be divided into:

- Agrosilviculture: combinations of food crops and woody perennials.
- Silvopasture: combinations of woody perennials and grass/fodder for livestock.
- Silvofishery: combinations of woody perennials and fish resources.
- Agrosilvopasture: combinations of food crops, woody perennials and grasses/fodder for livestock.

This paper focuses on agroforestry systems, especially silvopasture, in the Asia-Pacific region.

* Forest and Nature Conservation Research and Development Centre, PO Box 165, Bogor 16001, Indonesia.

† Asia Pacific Agroforestry Network (Apan), PO Box 481, Bogor 16004, Indonesia.

Overview of Agroforestry in Asia and the Pacific

The countries within Asia and the Pacific contain five broad agroecological zones: lowland humid tropics; upland humid tropics; arid and semi-arid tropics; temperate uplands; and alpine uplands. The population density in some parts of the region is high, and in certain parts still sparse. The agroforestry systems within the country may be: (1) farm-based, which includes homestead agroforestry, woodlots, commercial tree crop systems, and silvopasture systems; or (2) forest-based, which includes shifting cultivation, resettlement on forest lands, and silvopasture systems. Modifications of each agroforestry system may occur, depending on the ecological and socioeconomic conditions of the local area.

In nearly all countries, forest areas are under increasing pressure due to population growth and increasing conversion of forest lands to permanent agriculture or other purposes. Traditional agroforstry practices have evolved to meet the subsistence food, fodder, fuelwood, fibre and cash requirements of rural households. Where people are still living in the forests (e.g. tribal communities in India and Thailand) or still surrounded by abundant forests (e.g. Laos, Philippines and Indonesia) they practice shifting cultivation and harvest a number of nonwood forest products for commercial or subsistence purposes. If they live in coastal areas, mangrove forests are often integrated with fish, prawn and crab culture (e.g. Vietnam, Indonesia) to form various silvofishery systems.

In the case of settled agriculture, trees are extensively integrated in the farming system in both dense and sparse population situations. Agroforestry systems in high population areas often act as a buffer against fuelwood deficits. Trees planted around farms are carefully selected and integrated into the farming system. Very specific tree and crop combinations have evolved for the different agroecological zones. A number of commercial tree-crop agroforestry systems such as tea, coffee, rubber and coconut cultivation involve inter-cropping with annual crops and the integration of livestock. Farmers who live near forest areas in densely populated regions (e.g. Thailand, India and Nepal) graze their cattle or collect fodder from the forest.

The major challenge that exists for agroforestry in the region is the need for greater collaboration between agricultural and forestry research and extension agencies within each country.

The working group on livestock in the International Workshop on Developments in Procedures for Farming Systems Research, held in Puncak, Bogor, 13–17 March 1989, suggested solutions/improvements for large ruminants, including the establishment of multipurpose legumes, grasses, trees, shrubs, and other fodder crops. For small ruminants, feed security or seasonal availability requires stress on green feed/fodder conservation. For nonruminants, onfarm trials with indigenous pigs and chickens should be carried out to address improvements in feed security. These trials can be done in relation to cropping pattern trials. Cereal and legume grain crops like root crops, sorghum, pigeon pea, cowpea, and rice can contribute almost 30–40% to total feed. Trials should also be carried out to test suitable housing designs or sheds in semiconfinement. Floor space requirements, animal manure disposal and compost-making also need to be addressed (Sukmana et al. 1989).

Where the available agricultural area is limited, the development of forage gardens is usually recommended. The benefits from an intensive feed garden include (International Institute of Rural Construction 1992):

- Provision of renewable source of nitrogen-rich and palatable fodder, fuel and green manure.
- Curbing of soil erosion, conservation of soil moisture and increased soil fertility.
- Increases in the productivity of a given piece of land by the interplanting of diverse species of fodder trees, shrubs and grasses.
- Provision of a stable agricultural systems for semi-arid, tropical, drought-prone areas and other adverse environments.
- Reduction in the danger of toxicity problems from noxious weeks and contaminated, poisonous, fodder.

Silvopasture Systems

Bangladesh

Due to the prevailing sub-humid tropical climate there are no pasture lands in forest areas. However, when forest areas are degraded they are replaced by grass and shrubs. These forest areas, especially those in the Chittagong Hill Tracts, are grazed by cattle and other livestock.

The taungya system has been used in the past by the Forest Department to establish teak plantations (*Tectona grandis*), sal (*Shorea robusta*) and other species. This system of agroforestry is no longer used for plantation establishment because it has not always been successful.

India

Indian farmers have integrated crop farming with large numbers of livestock. Most of the livestock graze freely in village grazing lands, and also in the adjoining forest lands, where the villagers have grazing rights. Livestock also graze at large in agricultural fields during the fallow season. This is well regulated by traditional and social practice.

Grassland and tree management in the semi-arid zone

This system is practiced in Andhra Pradesh (AP), Karnataka, Tamilnadu, Maharashtra and Madhya Pradesh (MP) on the Deccan plateau. The system is locally called 'kanchas'. The kanchas are owned by the cultivators, although some are with the government forest departments. The grasses fall mainly in the *Sehemia-Dicanthium* grassland type, grow quickly and can reach a climax stage in 4–10 years depending on location and site conditions (Tejwani 1987).

Commonly planted trees are *Eucalyptus* hybrid, *Casuarina equisetifolia, Borassus flabellifer* and *Phoenix sylvestris.* Trees are lopped for fodder and fuel. Custard apple, mango, zizyphus and tamarind fruits are collected for home consumption. Neem (*Azadirachta indica)* fruits are collected for sale; mahua (*Madhuca latifolia)* fruits yield edible oil and its flowers are used to brew an alcoholic drink.

Grassland and tree management in the arid zone

The importance of *Prosopis cineraria* and *Ziziphus nummularia* in agrosilviculture systems in the arid zone is described above. These two species play a vital role in silvopasture systems. *P. cineraria*, when cut above ground level, produces numerous new buds that give rise to several new shoots. These in a years time assume a bushy structure. The coppiced shoots are continuously grazed leading to a 'cushion' form of the crown (Saxena 1984). As in the case of agricultural crops, *P. cineraria* is compatible with grass (Shankar 1984) *Z. nummularia* has remarkable powers of regeneration through root suckers. Apart from leaf fodder, mature *Ziziphus* yields about 3–5 kg fruit per bush growing in a 150–250 mm rainfall zone (Saxena 1984). It does not yield fruits in agricultural lands, as it is cut every year.

Nepal

Cold arid and sub-arid regions

Grazing in alpine pastures and temperate forests by communities who practice transhuman silvopasture is an outstanding example of resource management in the upper mountain and hill regions of Nepal. The livestock graze subalpine and alpine pastures (3000–4000 m elevation) in spring and summer, and as cold weather approaches they move down to graze in temperate forests (2000–3000 m elevation) during autumn and winter. The forest-derived fodder comes from conifers, birches and dwarf rhododendrons. The livestock are hardy yak (*Bos grunniens)* and wak (yak and cow hybrid) at high altitudes and a mix of goats, sheep and buffalo at lower, yet cold altitudes. These people also practice a sort of 'ephermeral' agriculture during the extremely short growing season and grow potato, millet and barley (Tuladhar 1990). All those who practice this system are of mongoloid groups.

Temperate to subtropical regions

The temperate and subtropical hilly regions are very densely populated, by both humans and livestock. Silvopasture in these regions is practiced at two levels of management—community and individual. The community-level silvopastoral activities are carried out on lands which are vested in the community for management. The unit of management is usually sub-watersheds with an elevation range of 1500 to 3000 m, or subtropical to temperate. Farmers adopt a cut-and-carry mode for stall feeding. Tuladhar (1990) calls this practice a 'protein bank'. The people involved are a caucasoid race from India and early mongoloid migrants from Tibet.

A similar system is practiced by individual farmers at 2000 to 3000 m elevation near hill tops and ridges. The lands have been 'claimed' from the contiguous forest. They are managed to promote grass ('khar') as well as fodder trees (*Ficus semicordate*). It is estimated that forests provide over 42% of the animal fodder supply. Over 136 species of trees and shrubs are used for fodder (Panday 1982). Information on the feeding value of these fodders is limited. Productivity of grazing lands is low.

Pakistan

Silvopasture is practiced extensively in Pakistan. The rangelands of Pakistan have been classified in 10 groups according to their geographical and climatic conditions: (i) alpine pastures (very cold and arid); (ii) trans-Himalayan grazing lands (cold desert); (iii) Himalayan forest grazing lands (sub-tropical to temperate); (iv) Pothwar scrub rangelands (semi-arid to sub-humid); (v) Thal desert; (vi) DG Khan rangelands; (vii) Cholistan desert; (viii) Tharparkar desert; (ix) Kohistan desert; and (x) Baluchistan inter-mountain rangelands (rangelands serially numbered from 4 to 10 being hot-arid and deserts). A large number of tree and shrub species according to agroecological and edaphic conditions, are associated with the grasslands. The tree, shrub and grass species, and the range conditions in which they are found, are extensively described in Mohammad (1987, 1989).

Some of the important multipurpose tree and shrub species which provide good fodder for livestock are summarised in Table 1.

The government-controlled forests of Pakistan (area 45 790 km^2) contribute as much as 3.2 million t of grass annually. A similar amount is contributed by

Table 1. Multipurpose trees and shrubs used for fodder, Pakistan.

Zone	Fodder tree and shrub species
Temperate	*Quercus incana, Q. semicarpifolia, Q. dilatata, Robinia pseudocacia, Amorpha fruticosa*
Humid	*Grewia oppositifolia, Ceretonia siliqua, Robinia pseudocacia, Amorpha fruticosa, Morus alba, Albizia* spp.
Sub-humid	*Olea cuspidata, Morus alba, Albizia lebbeck, Acacia nilotica, A. modesta, A. aneura, A. victoria, A. cyanophylla, Ziziphus mauritiana, Z. nummularia, Gleditschia tricanthos, Leucaena leucocephala, Ceretonia siliqua, Tecoma undulata*
Semi-arid	*Ziziphus mauritiana, Z. nummularia, Prosopis cineraria, Morus alba, Albizia lebbeck, Acacia modesta, A. victoria, A. aneura, Tecoma undulata, A. nilotica, A. jacquemontii.*
Arid	*Prosopis cineraria, Acacia nilotica, A. senegal, A. jacquemontii, A. aneura, A. victoria, Salvadora oleoides, S. persica, Tecoma undulata.*

the rangelands: 61 160 km^2; 3.4 million t of grass annually (Tables 2 and 3).

Sri Lanka

Whenever grasses are grown under coconuts or in home gardens, the former is a silvopasture and the latter an agrosilvopasture practice.

Indonesia

Most practices have livestock components so they may be described as agrosilvopasture systems. The cattle and buffalo in Java are stall-fed with fodder collected from home gardens, along irrigation channels and road sides during the crop growing season. In the fallow season, animals are herded on the arable lands of the village, and may also receive straw, hay and other crop residues (Wiryosuhanto 1990). Cattle and buffalo contribute little to the farm family diets, they are used mainly for draught power, provision of manure and as a means of accumulating capital. Sheep and goats are raised as a source of meat, manure and money.

Three strata forage system

An innovation to combine crops, grasses, trees and livestock, called the Three Strata Forage System (TSFS) was introduced in 1980.

This system, especially for smallholder dryland farming areas in Bali, was started in 1980 and some results have been reported (Nitis et al. 1989; Nitis and Lana 1990). Conceptually, TSFS envisages planting of crops, grasses, legumes, shrubs and fodder trees in three horozontal strata. Since the land holdings are small in Java and Bali, a 0.25 ha model area (50 m × 50 m) is adopted. It is divided into three parts:

The first part, 1600 m^2, is the core area (40 m × 40 m), and is located in the middle of the plot, for food crops (maize, soybean, cassava).

The second part is the peripheral area of 900 m^2, the remaining part of the plot, for planting grasses (*Cenchrus ciliaris, Panicum maximum, Urochloa mosambiensis*), and legumes (*Stylosanthes guyanensis, Stylosanthes hemata, Centrosema pubesence*).

The third part is the farm plot boundary, 200 m in length, where shrubs such as *Leucaena leucocephala, Gliricidia sepium* and *Acacia vilosa* at 10 cm spacing are planted; and fodder trees such as *Ficus poacellie, Lannes corromadilica* and *Hibiscus tillaeceus* at a spacing of 5 m are planted.The number of shrubs is 1000 each of *Leucaena* and *Gliricidia*, and 14 trees each of *Ficus*, *Lannes* and *Hibiscus*. The cattle are introduced in the beginning of the second year, when grasses, legumes and shrubs are available for fodder. The trees are ready for lopping at the beginning of the fourth year.

TSFS was compared with a non-Three Strata Forage System (NTSFS). It was observed that while the crop straw yield was reduced by 40% the grass and legume fodder yield was increased by 77%, and tree fodder yield was increased by 121% in the TSFS as compared to NTSFS. It was then concluded that while TSFS could support 3.2 cattle, the NTSFS could support only 2.1 cattle. The TSFS also produced 462% more fuelwood than the NTSFS (Nitis et al. 1989). While it is expected that the grain yield of crops would have decreased (due to the decrease in cropped area), there has been no reports of this parameter of the system.

There are a number of strengths, weaknesses and opportunities with respect to biophysical, economic, environmental and social aspects of TSFS. However, it appears that the system needs to be moved to the demonstration and development stages before it can be widely accepted. The biggest handicap appears to be obtaining a 0.25 ha plot of land in sloping dryland areas to layout the three strata system.

Lao PDR

Livestock form an integral part of sedentary and shifting agroforestry systems. The cattle are grazed on fallow fields. Other animals raised include pigs, goats, sheep, and poultry. Fish are an important source of protein and aquaculture is practiced in areas with permanent ponds (GOL 1991).

Philippines

Farmers have integrated crops with livestock. Smallholder farms depend on tree fodder and crop residues from agricultural lands. On small land holdings the animals are stall-fed by cutting and carrying the fodder. Land under coconut is also grazed. Whenever animals are integrated with farm-based agroforestry practices, they may be classified as agrosilvopasture practices.

Fodder tree species that are important include: *L. leucocephala, G. sepium, Sesbania grandiflora, Trema orientalis, Pithecollobium dulce, Samanea saman, Erythrina variegata, Artocarpus heterophyllus,* and *Passiflora edulis* (Florido 1990).

Thailand

Normally cattle are raised and grazed on public land. During the rainy season when paddy is grown on the plains, cattle may be allowed to graze in the natural forest or in government tree plantations. In privately owned coconut, rubber, or oil palm plantations, farmers may feed cattle by growing shade-tolerant grasses (Petmak 1990; Thongmee 1990; Topark-Ngram 1984).

Vietnam

Livestock are maintained for meat and draught power. The cattle are grazed in the natural forests. Traditionally cattle are allowed to graze freely, especially in the midhills and mountains. A number of grasses occur naturally and some of them are cultivated. Fodder tree species recognised are: *Tephrosia candida, Sesbania grandiflora, L. leucocephala, Acacia auriculiformis, Streblus asper, Ficus auriculata, F. racemosa, T.rems orientalis, Bauhinia* spp., *Broussonetia papyrifera, F. fulva, F.hespida, F. gibbosa, F. gallose, F. laccar, F. variegata, Garuga pinnata* (Hoang Hoe 1990).

Table 2. Grass production from forest lands in Pakistan.

Type of forest	Area ('000 ha)	Estimated yield (t/ha)	Total yield ('000 t)
Coniferous	1959	1.0	1959
Scrub	1726	0.5	863
Irrigated plantations	234	0.5	117
Riverine	296	0.3	89
Coastal (leafy fodder)	347	0.3	104
Linear plantations	17	1.0	17
Total	4579		3149

Source: Pakistan Forest Research Institute (Jan 1990).

Table 3. Grass production from rangelands in Pakistan.

Province	Area ('000 ha)	Estimated yield (t/ha)	Total yield ('000 t)
NWFP	150	1.7	255
Punjab	2806	0.8	2245
Sind	490	0.6	294
Baluchistan	372	0.1	37
Northern areas	2104	0.1	210
Azad Kashmir	194	1.7	330
Total	6116		3371

Source: Pakistan Forest Research Institute (Jan 1990).

China

According to Zhu (1994), silvopasture in China has been practiced for a very long time. During the Han Dynasty (260 B.C.–220 A.D.), administrators recommended the development of trees together with the raising of livestock and crops according to different site conditions.

Agroforestry as a traditional farming system had been conducted in China for millennia. This system is accepted by more and more farmers. The agroforestry system is also practiced in arid and semi-arid zones.

Agroforestry characteristics in this area include the establishment of forest networks around agricultural land, orchards, and pasture lands to avoid the damage of wind and sand storms. Tree species are used as fodder, timber and fuelwood. Rational combinations of pasture and tall trees, shrubs, and grass are established in the silvopasture areas. This system is called 'aerial pasture' by the local farmers.

Farmers are increasingly interested in tree–grass–fish models in some areas of China. In Zhujiang River Delta of Guandong Province, fruit and cash trees such as lychee, Chinese fan palm, banana etc. are planted around fish ponds, and pens for pigs and other animals are built close to the ponds. Animal excrement can be further used as fodder for fish.

Papua New Guinea

According to Afing (1991), the modern agroforestry concept in Papua New Guinea is still new. The Forest Research Station in the Eastern Highlands province initiated silvopasture trials in 1972 and in 1974 and held a successful field day. In 1988 the Department of Agriculture, in collaboration with the Department of Forests, initiated Multipurpose Tree Species (MPTS) trials to identify various potential tree species for agroforestry purposes. Tree species included *Acacia angustissima, Gliricidia septium,* various species and various varieties of leucaena, *Calliandra calothyrsus, C. houstoniana, Cassia didymobotrya* and *Casuarina oligodon.* These trials were established at the Highlands Agricultural Experimental Station, Aiyura and Lowland Agricultural Station Bubia with tree seeds supplied by the National Tree Seed Centre at Bulolo.

Future Directions for Agroforestry and Silvopasture Research and Development

It is believed that agroforestry can be an appropriate land use for achieving sustainable development in environments where deforestation and degradation of forest resources have reached alarming levels, or in areas where land for agriculture is limited.

Based on the expert consultation on agroforestry in the Asia–Pacific region held at the FAO Regional Office in Bangkok, from 15 to 18 May 1990, the need for agroforestry was recognised for various reasons, including:

- restoration of forest and tree resources/conservation of remaining ones;
- ecological stabilisation of hilly areas; and
- for socioeconomic development of the rural sector.

The consultation endorsed the following elements of strategies adopted by countries as generally applicable:

- Allow economic forces to attract farmers to adopt agroforestry systems (Nepal).
- Establish government-sponsored incentives (share of yield) to attract farmers to agroforestry in forest areas (China).
- Assist farmers to enjoy more equitable distribution of benefits from sustainable agroforestry on government lands (Indonesia).
- Use agroforestry demonstration areas as a means to acquaint farmers with agroforestry (Laos).
- Provide extension, technical assistance and other government aid (Nepal).
- Use research and demonstration to assist people adopt modern agroforestry (Papua New Guinea).
- Approach agroforestry promotion in a multipronged manner (through policy makers, researchers, extensionists) and incentives to agroforestry farmers (Sri Lanka).
- Provide education and training for all extension officers to promote agroforestry on private lands/uplands/forest lands and on government lands.
- Exchange information and experience among countries which face similar circumstances.

The consultation called for greater efforts to integrate forestry with other sectors of the economy. Forestry, crop production and livestock husbandry and agroforestry, in some ways, were closely intertwined. There might be special need in some countries to adopt agroforestry practices to increase fodder supplies.

References

Afing, W.P. 1991. Agroforestry in Papua New Guinea. In: Mellink, W., Rao, Y.S. and MacDicken, K.G., ed., Agroforestry in Asia and the Pacific. RAPA Publication, 1991/5, 133–137.

Florido, L.V. 1990. Agrosilviculture in relation to livestock production (Philippines). Regional Expert Consultation on Agrosilviculture to Support Animal Production in the Asia and Pacific Region. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

GOL (Government of Laos) 1991. National Agriculture and Forestry Research Programme 1991–1995. (Cited in Tejwani and Lai 1992.)

Hoang Hoe. 1990. Integrating forestry and grazing practices to establish silvopastoral systems in Vietnam. Regional Expert Consultation on Agrosilviculture to Support Animal Production in Asia and the Pacific Region. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

International Institute of Rural Reconstruction, 1992. Agroforestry Technology Information Kit (ATIK) 4, Livestock and Poultry Production. Silang, Cavite, Philippines, International Institute of Rural Reconstruction.

Jan, A.U. 1989. Grazing rights in forest and open pastures in Himalayas. Seminar on Range Management in Himalaya (mimeograph). (Cited in Tejwani and Lai 1992.)

— 1990. Forest and livestock grazing in Pakistan. Regional Expert Consultation on Agrosilviculture to Support Animal Production in the Asia and Pacific Region. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

Mohammad, N. 1987. Pakistan's experience in rangeland rehabilitation and improvement. FAO. (Cited in Tejwani and Lai 1992.)

Mohammad, N. 1989. Rangeland management in Pakistan. Kathmandu, Nepal, International Centre for Integrated Mountain Development. (Cited in Tejwani and Lai 1992.)

Mellink, W., Rao, Y.S. and MacDicken, K.G., ed., 1991. Agroforestry in Asia and the Pacific. RAPA Publication 1991/1.

Nitis, I.M. and Lana, K. 1990. Konservasi Lahan Kritis dengan Pola Tiga Strata dan Pemanfaatannya untuk pengembangan Peternakan sapi Bali. National Seminar on Sapi Bali. Faculty of Animal Husbandry. Udayana University. Bali, Indonesia. (Cited in Tejwani and Lai 1992.)

Nitis, I.M., Lana, K., Suarna, M., Sukanten, W., Rutra, S., and Arga, W. 1989. Tri strata system for cattle feeds and feeding in dry farming area in Bali. Udayana University. Bali, Indonesia, Faculty of Animal Husbandry. (Cited in Tejwani and Lai 1992.)

Panday, K.K. 1982. Fodder trees and tree fodder in Nepal. Switzerland, Swiss Federal Institute of Forestry. (Cited in Tejwani and Lai 1992.)

Petmak, P. 1990. Traditional agroforestry systems in Thailand. Expert Consultation on Agroforestry in the Asia Pacific Region. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

Saxena, S.K. 1984. Khejri (*Prosopis cineraria*) and bordi (*Ziziphus mummularia*) multipurpose plants of arid and semi-arid zones. In: Shankarnarayan, K.A. ed., Agroforestry in arid and semi-arid lands. Jodhpur, India, Central Arid Zone Research Institute, Publication No. 24, 111–121. (Cited in Tejwani and Lai 1992.)

Shankar, V. 1984. Inter-relationships of tree overstorey and understorey vegetation in silvopastoral systems. In: Shankarnarayan, K.A. ed., Agroforestry in arid and semi-arid lands. Jodhpur, India, Central Arid Zone Research Institute, Publication No. 24, 143–149. (Cited in Tejwani and Lai 1992.)

Sukmana, S.P.A. and Mulyadi, D.M., ed., 1989. Report of Working Group II: Livestock. Proceedings of an international workshop on developments in procedures for farming system research, Puncak, Bogor, 13–17 March 1989, 390.

Tejwani, K.G. 1987. Agroforestry practices and research in India. In: Gholz, H.L., ed., Agroforestry: realities, possibilities and potentials. Dordrecht, Holland, Martinus Nijhoff Publishers, 109–136. (Cited in Tejwani and Lai 1992.)

Tejwani, K.G and Lai, C.K. 1992. Asia-Pacific agroforestry profiles. Asia-Pacific Agroforestry Network. APAN Field Document No. 1. Agroforestry Systems Research and Development in the Asia and Pacific Region (GCP/RAS/133/JPN). Bogor.

Thongmee, U. 1990. Agrosilviculture to support animal production in Thailand. Regional Expert Consultation on Agrosilviculture to Support Animal Production in the Asia and Pacific Region. FAO Regional Office for Asia and the Pacific Region. Bangkok, Thailand (mimeograph) (Cited in Tejwani and Lai 1992.)

Topark–Ngram, A. 1984. Pasture research and development in Thailand. In: Asian pasture—recent advances in pasture research and development in Southeast Asia. FFTC Book Series No. 25. Taiwan, Republic of China, 58–64 (cited from Thongmee 1990). (Cited in Tejwani and Lai 1992.)

Tuladhar, A.R. 1990. Agroforestry in Nepal. Expert Consultation on Agroforestry in the Asia and Pacific Region. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

Wiryosuhanto, S.D. 1990. Utilization of forest land for fodder production to support livestock production in Indonesia. Regional Expert Consultation on Agrosilviculture to Support Animal Production in the Asia and Pacific Region. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand (mimeograph). (Cited in Tejwani and Lai 1992.)

Zhu, Z.H. 1994. Agroforestry research, development and training for China. Inter-regional Meeting on Agroforestry Research, Education and Development for Africa, Asia, and Latin America, 3–7 May 1994, ICRAF, Nairobi, Kenya.

Tropical Forest Conservation in Indonesia: Problems and Solutions

T. Silitonga*

Abstract

The problems associated with the conservation of tropical forests in Indonesia arise almost entirely as a consequence of timber harvesting for industrial wood, and forest clearing for nonforest activities. This paper discusses the issues confounding the implementation of appropriate forest management and outlines the approach being taken by the Indonesian Government to accelerate the adoption of appropriate management strategies.

INDONESIA is made up of 14000 islands spread out along the equator between the Indian and Pacific oceans and between the Asian and Australian continents. The total land area is 191 million ha of which 113 million ha, or nearly 60%, will ultimately be maintained as productive and protected forest.

The forest regions contain some 1250 species of birds, more than 9000 species of fish and 600 species of mammals and reptiles. It is accepted that we have an obligation to conserve these resources so that they might be passed on to future generations.

In recent decades Indonesia has experienced rapid economic growth. This, coupled with high population growth, has resulted in forests being used for agricultural development, human settlement and industrial activity such as mining. More than 30 million ha of formerly forested land is now used for nonforest activity.

In the past decade forests have become the focus of worldwide attention. They are major contributors to human welfare, providing products essential to our survival and socioeconomic development. Agroforestry, because of its potential to generate additional products and therefore income, is particularly important. It offers the opportunity to increase food production without compromising conservation and environmental considerations.

* Department of Forestry, Republic of Indonesia, Jakarta.

Environmental stress often has been considered the result of increasing demand on scarce resources. But people living in or near forests who are poor have had few alternatives to destroying forests to survive. They have cut down the forest, overgrazed the grasslands with their livestock, and as their populations have increased they have crowded into often already crowded cities.

The historic United Nations Conference on the Human Environment in Stockholm in 1972 brought global environmental problems to the fore. In 1992 the United Nations Conference on Environment and Development (UNCED) in Brazil produced Principles of Forests (Agenda 21) in an effort to combat deforestation. Importantly though, the conservation and/or development of forests is not an objective per se but rather a tool to be employed in the process of achieving national and international development priorities. What is needed is a balanced view of the forester's economic, social and environmental functions, together with an understanding of how these functions operate and interrelate.

National Policy on Forests

The forests of the ASEAN countries cover an area of 190 million ha, representing 62% of the total land area of 300 million ha. The corresponding percentage for the world is 30%.

Country by country national forest policies differ mainly due to very different tenure (ownership) arrangements. In this regard Indonesia is somewhat fortunate in as much as the government holds exclusive jurisdiction over the forest lands. The primary source of authority for forestry administration is the *Basic Forestry Act, No. 5. 1967*, which outlines the state's mandate to control, regulate, manage and administer the national forest lands and all forest resources.

A national forest landuse plan was introduced in 1982. According to this plan forest lands are divided into categories based on primary function — protection, conservation and production. Assigning forests to these categories has been done by developing inventories using Landsat-derived images and aerial photography. Inventories from ground surveys and subsequent mapping, concentrating first on the production forests, are progressively being assembled.

In 1982 an Act was passed to formalise the management of flora and fauna. This Act has as its main objectives:

- to achieve harmonious relationships between human beings and the environment as a means of national development;
- wise use of natural resources; and
- to meet the needs of present and future generations.

A more recent Act — *Conservation of Living Resources and Ecosystems (Act No. 5, 1990)* — is providing an expanded legal basis for protection and conservation areas such as national parks, nature reserves and wildlife sanctuaries. One of the most important aspects of this Act is its concern with sustainable use of living resources and their environments.

Indonesia is committed to joining the global effort for conservation and sustainable development of the world's forests. Indonesia's national forest policy reflects the intentions of the UNCED agreement, especially the Principles of Forests and Agenda 21. The policies are also in agreement with the International Tropical Timber Organisation (ITTO) decisions concerning guidelines for the sustainable management of natural and plantation forests and the criteria for measurement of sustainable tropical forest management.

To achieve maximum benefit from sustainable forest use, the Indonesian 1994–1998 economic development plan for the forestry sector is orientated toward strengthening the viability of the forest-based industries, forest resource conservation, and reinforcement of improvements to environmental conditions. These are supported by corresponding rules and regulations. Perhaps the most significant component of the present policy is its attempt to address the moral questions surrounding the role of forests for people, particularly those living in or near the forests. The participation of these people in forest development must be encouraged if conservation is to be achieved. In many cases the complexity of Indonesia's land tenure regimes have become controversial issues in the implementation of forest policy.

In order to reinforce these polices, regional forest offices have been established in 27 provinces, and more than 1600 new officials have been recruited since 1985. The government also is consistently promoting and providing opportunities for the participation of all interested parties including local communities, industry, nongovernment organisations and forest dwellers in the planning, development and implementation of national forest policies.

Conservation of Forests

Forest protection policies, specifically for Indonesia, are based on the desire to improve the living standard of the people and be in harmony with the environment. All forms of natural life and ecosystem types within the country are covered by the policies, and both present and future generations are considered.

Growing population and ever-increasing competition for land, together with inadequate management in the past, have caused various degrees of degradation in the forests. It requires a strong political will and significant financial resources to counter these pressures. Forest areas should as far as possible be kept intact and it is for this reason Indonesia has determined that 34% of its forests shall be totally protected.

It is recognised that forests must satisfy the demand for forest products now and into the future, but at the same time the forest ecosystem, which protects the soil and allows ongoing regeneration that in turn preserves biodiversity, must not be harmed in any permanent way.

The demand for forest products currently exceeds the sustainable supply available from natural forests and therefore increased areas of plantation forests are needed. In the last 5 years Indonesia has established more than 1 million ha of fast-growing trees throughout the country. Despite this it is recognised that the harvesting of timer must be at a rate below the timber producing capability limit and thus on a sustainable basis.

The implementation of regulations regarding the sustainable use of forests, irrespective of ownership, is still confounded by issues surrounding land tenure and the traditional right to cultivate forest lands. Law enforcement is often difficult. Law awareness campaigns combined with extension and education programs are of paramount importance in stabilising land tenure queries.

As far as possible, in Indonesia, forests are managed to support the multiple function namely: the provision of nontimber products, cash crops and forage for animals.

It is realised that clearing of the forest for agriculture is the major cause of forest decline. Settlements, shifting cultivation, illegal cutting and wildfire also pose a major threat. Most of these activities stem from the poor economic conditions of the people living adjacent to forest areas. Improving the prosperity of these people is therefore an important factor in protecting forests from degradation. The state forest enterprises and a number of forest-concession holders have launched initiatives to introduce sylvofisheries, sylvopasture, bee keeping, crocodiles, and monkey enterprises throughout Indonesia.

Unregulated forest clearing in the past has left some 15 million ha of land in a degraded forest state or as dry grassland. Despite the introduction of more stringent regulations, until recently the rate of such degradation had not slowed. A civic-mission and social project carried out by the concession holders is one of the efforts being made to reduce the problems created by shifting cultivation.

In 1982–1983 the area affected by shifting cultivation was estimated at 9.3 million ha. A more recent estimate by the World Wide Fund for Nature gave a figure of 20 million ha. It is clear that any attempts to reduce the impact of shifting cultivation should consider all related issues, including land use, culture, land tenure and other socioeconomic factors. Localised programs for harmonisation of shifting cultivation are likely to be more successful. A holistic approach is essential.

Forest management should be integrated with management of adjacent areas so as to maintain an ecological balance and sustainable production. The provision of employment for people in the neighbourhood is also important.

The problems that hinder efforts to attain conservation and sustainable use of forests stem from a lack of options available to local communities who are economically and socially dependent on forest resources.

Despite the increasing demand for animal products, requests for permission to convert forests to pasture lands have been meagre. Traditional farming systems on a small scale still out-number the nontraditional large-scale enterprises. This indicates that investment opportunities are available despite the fact that the government is still to develop rangelands legislation. Because rangeland ecosystems produce forage which can be most efficiently harvested and converted to human food by animals, the development of policies for rangeland management is extremely important.

If properly managed most rangeland ecosystems can be grazed without undue risk to soils, watershed, wildlife habitat and ecotourism.

Wildlife Conservation and Genetic Diversity in Agroforestry Systems in Asia

A.W. English*

Abstract

The countries of Asia contain most of the world's remaining forests, with these playing a vital role in the lives and livelihoods of people in the region.

Agroforestry systems vary greatly in the ways in which trees are integrated with animal and agricultural production, but there is a common theme of overutilisation and degradation of forest environments in all countries. Rapidly increasing human populations place pressure on accessible forests, and on the animals which need these forests for survival. If the diverse wildlife fauna of Asia is to be preserved for future generations, there will need to be not only an increased intensity of current programs of forest management, reforestation, and wildlife conservation, but also the pursuit of new initiatives in the use of wildlife. There are good prospects for the development of new industries based on wildlife species, as an integral part of agroforestry systems of the future. There must be an awareness that environmental protection and conservation of natural resources are essential for sustained economic development. Nature tourism (ecotourism) alone has enormous potential in the region, if it is well managed and its effects are closely monitored.

THERE is an increasing perception in many countries that development that seeks to raise human living standards must be accompanied by measures which do not add to the depletion and degradation of the earth's natural resources. Such resources are important not only for their current and potential economic value but also for their role in maintaining ecological processes, such as soil and water regulation, within and beyond their boundaries (Dixon and Sherman 1990). This paper addresses the issues of wildlife conservation and use within the context of sustainable agroforestry in Asia. The region is affected by a vast complex of ecological and socioeconomic factors, and it is not possible yet to define in every country all the issues that are relevant. Examples will be used to illustrate the potential for actions that will not only result in the preservation of existing levels of biodiversity, but also have an excellent chance of improving or at least maintaining the productivity of forests in the region. The countries referred to are: Bangladesh, Bhutan, China, India, Indonesia, Malaysia, Myanmar, Nepal, and Pakistan.

Agroforestry Systems in Asia

The simplest definition of agroforestry appears to be 'the use of trees in farming systems, in which farmers combine the production of crops, trees, livestock, fish or other components'. The challenge for those seeking to improve or modify such systems is to do so in ways which are ecologically and socioeconomically sustainable (Lai 1992). Given the critical problems facing all countries in the region — rural poverty, escalating populations, landuse conflicts, deforestation, and soil and watershed degradation — it is clear that any attempt to focus on the conservation of wildlife species must be accompanied by a clear definition of the likely benefits to the countries and communities concerned. It will not be enough to use arguments based on the perceptions of industrial countries about the need to prevent the extinction of species for philosophical reasons — especially given the record of these same countries in achieving the extinction of a large number of their own species over the last 200 years or so.

* Department of Animal Health, University of Sydney, Camden, NSW 2570, Australia.

However, as living standards rise in the countries of Asia, as a consequence of increasing industrial and agricultural production, it is reasonable to assume that there will be some changes in emphasis at both community and national level — with factors such as national pride, and a determination to abide by international conventions, leading to policies which directly affect the conservation of such icons as the tiger, the elephant and the rhinoceros. Much remains to be done though — people living in poverty, or barely above subsistence level, have little or no concern for such matters. The challenge is to integrate at least some protected areas into the overall national economies of the countries in question, rather than such areas being very lightly used, which has been largely the case in developing countries.

Forests play an essential role for populations across all countries in Asia. They provide fuelwood, shelter, fodder for livestock, food, medicines and other products. There is an increasing awareness of the potential of forestry lands in livestock production. Forests also preserve watersheds and water quality, prevent soil erosion and landslips, and are the habitat of a vast array of animals and birds, many of which are now threatened with extinction. Animals as diverse as primates and fruit bats (flying foxes) play an essential role in pollination and seed dispersal and germination within forests, with the adverse effects of the creation of imbalances in fauna perhaps not being noticed until too late.

Livestock productivity is low across most of the region, generally due to the poor quality or shortage of fodder. In addition, there are seasonal factors which place strains on animal production systems. There has been a general tendency to bring more land into agricultural production, with the consequent clearing of forests occurring at an alarming rate over the last few decades. It is estimated that 7 million ha of tropical forests are cleared annually. Some scientists believe that about 60 000 of the world's 240000 plant species and perhaps even higher proportions of vertebrates and insect species are now in danger of extinction in the next three decades, unless deforestation is halted. Furthermore, one of the concerns is that there is inadequate information on the fauna and flora of tropical forests, and much may be lost before it is described. The potential loss of useful and significant life forms is of consequence to the whole world.

This leads to the conclusion that while low livestock productivity must be addressed — by control of animal numbers, improved husbandry practices, better disease control, and use of superior genetic material — this cannot occur at the expense of intensified use of agroforestry resources, unless there is an accompanying change in the way forests are managed. If measures to improve livestock production include increased use of existing forests, without serious attempts to produce alternative solutions, then not only will this be an unsustainable situation, but there will be serious consequences for the wildlife species which still rely on those forests as habitat.

In seeking alternative solutions to the continued destruction or over-use of existing forests, there must be a willingness to examine all possible solutions. The formation in 1991 of the Asia-Pacific Agroforestry Network (APAN) was an acknowledgment of the need for all countries in the region to seek better management of their forests. The network brings together the collective expertise of government agencies, universities, nongovernment and grassroots organisations, to collaborate on research, training and information-sharing activities. One of the Network's stated aims is to maintain the ecological security of the forests, while recognising the integral part that they play in the socio-cultural life of rural communities.

There is therefore an opportunity to examine the role which conservation and use of wildlife species can play within this context, so that not only is the incredible biodiversity which is supported by the forests guaranteed of preservation, but also the potential economic benefits from doing so are identified, and developed.

In exploring these issues, examples will be drawn especially from Nepal, which appears to be a microcosm of most of the points under debate, in seeking solutions to the major problems. With the present state of knowledge, it may be possible to identify the problems only in some cases. In particular, there must be close cooperation between the government departments of agriculture and forestry, to ensure that there is a systematic approach to both the planning and execution of new initiatives.

Use and Management of Forests

Any attempt at reducing the rate at which forests are being destroyed or degraded should begin with an examination of the forests themselves, and of the ecosystems they support. There are such vast differences between a mangrove forest in Thailand and an alpine forest in Nepal that no generalisations will suffice for specific action. At the same time consideration must be given to the nature of the agroforestry systems and practices prevalent in each case, so that these and other elements involved in the processes of degradation can be identified.

Agroforestry systems

The 10 countries participating in APAN are all tropical countries, with two population densities (dense and sparse) and five agroecological zones (lowland humid tropics, upland subhumid and humid tropics, temperate uplands and alpine uplands). This provides a possible combination of 10 situations based on the agroecology and population density, and of these, three do not occur in six or seven participating countries. Temperate and alpine situations under high population density occur only in India, Nepal and Pakistan. It is also necessary to divide agroforestry practices into farm-based and forest-based systems, to relate them to the people who are the focus of all agroforestry efforts. Where people are still living in forests (e.g. tribal communities in India and Thailand), or are surrounded still by abundant forests (e.g. Laos, Philippines and Thailand), they practice shifting cultivation and harvest a number of nontimber products from the forest for commercial or subsistence purposes. In coastal areas, mangrove forests are often integrated with fish, prawn and crab culture (Vietnam) to form various silvofishery systems (Tejwani and Lai 1992).

Any changes made to the existing situation must involve the promotion to the people of alternative systems of producing food, fuelwood, fodder and other products. The use of new species of animals and plants, and the development of nature-based tourism (ecotourism) should be considered. The bias toward exploitative use of natural areas must be replaced by a proper evaluation of the costs and benefits of establishing protected areas. These may permit a range of human interventions, from none at all (apart from scientific study and environmental monitoring), to multiple-use management areas which provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation (Dixon and Sherman 1990).

Nepal

Although Nepal has been chosen as the focus for this discussion, factors which are likely to be common to many other countries are considered. This is done to ensure that the major issues are canvassed, and that broadly-based solutions are offered. Where specific examples are relevant these will be discussed, and related when possible to the more general situation in the region.

Geography

Nepal has a total land area of 136 800 km^2, with 26 410 km^2 (19%) cultivated. Grazing areas, which are mostly in high mountain regions, account for 12% of the total land area. Forests occupy 38% of the geographical area, and constitute one of the major natural resources of the country (Pande 1992).

The population in 1988 was 18.7 million, and this is likely to rise to 24 million by the year 2000. Population density is extremely high. The vast majority (96%) of Nepalese are farmers who own less than 1 ha of land.

The over-use and degradation of arable land and forests has been catastrophic in Nepal. The number of livestock per unit of land is amongst the highest in the world. The major supply of fodder for ruminants comes from the forests, and from crop residues, supplemented at times by grasses from pastures, field terraces and planted fodder trees. It is estimated that 41% of the total feed supply is contributed by forests, with tree foliage and grasses contributing 31% and 10% respectively (Panday 1982). Forests also supply bedding materials for livestock, and fuelwood, which is the major source of energy. As a result, most of the forests in heavily populated areas up to 2500 m are over-utilised, and are seriously degraded and mismanaged.

The effects on wildlife are equally catastrophic. In order to determine where some progress could be made to improve or redress this, the agroforestry systems in use are examined. A similar exercise for each country in the region would identify the similarities across systems used in Asia, with the differences being quite apparent — such as the absence of mangrove forests in Nepal.

Farm-based agroforestry practices

Trees in and around agricultural fields

Much of the hilly terrain in Nepal is bench-terraced, especially the irrigated rice fields. Farmers do not grow trees in irrigated paddy fields, but they do grow them on rainfed terraces and on degraded land. These trees are usually multipurpose — used for fodder, fuelwood and timber, with fuelwood being the most important.

In the subtropical Terai in the south, where forest has been extensively removed for agriculture, farmers grow trees on farm 'bundhs' (earthen boundaries between fields), with these trees also being multipurpose. With only 5% of the 'bundh' perimeter so used, there appears to be considerable scope for improvement (Tuladhar 1990).

Such intensively-farmed areas are unlikely to support large wild mammals, unless these come from protected areas to feed on the crops. This is a relatively common occurrence around Royal Chitwan National Park (RCNP), with both rhinoceros and several deer species causing considerable crop damage at times. Thus, the attitude of the local people to the existence of sanctuaries is largely negative, with little incentive for them to view the wildlife as anything but a nuisance. Add to this the occasional death or serious injury caused by tiger, rhinoceros or sloth bear, and it is not surprising that villagers have negative perceptions of wildlife conservation.

Home gardens

Home gardens in Nepal are called tree gardens, and these are common in the Terai and hill regions. These have been developed largely as a result of villages exhausting their accessible forest resources a long time ago, but they are still not common in communities which have traditionally been silvopastoral seminomads (Tamang, Sherpa, Limbu and Rai communities in the mountains). About 200 fodder tree species are used in the hill home gardens, particularly *Ficus* species (Tuladhar 1990).

These gardens also are unlikely to support large wild mammals, but would certainly shelter small animals and birds. Animals such as weasels and martens prey on village poultry, and are not viewed with any sympathy.

Woodlots

In Nepal, natural stands of forest remain in the upper reaches, ridge tops, and along the stream banks of subwatersheds in the hills. These forest remnants protect agricultural fields from soil erosion, prevent drying up of water springs, prevent land slips and land slides, and maintain the natural ecology of streams. These stands of timber are managed by village communities, which by custom are allowed to extract fodder, fuelwood and small timber. In many cases there is a slow decline in the size of such stands of forest, but nonetheless they do provide suitable habitat for small mammals and birds, and in some cases could be critical habitat for those populations.

In the case of both the preceding systems, isolated populations of small mammals quite clearly suffer the risk of local extinction as the habitat dwindles, and as their genetic diversity is reduced.

Commercial crops

Tea is grown to a limited extent in the Terai, under shade trees selected for tea plantations in northeast India. Orchards of mango trees are intercropped with agricultural crops in the Terai, with other trees such as *Dalbergia sissoo* being used on the boundaries. Ginger, tumeric and cardamom are grown in the humid tropical climate of eastern Nepal, also under shade trees such as *Alnus* and *Albizia* species.

These commercial crops, with the associated trees, are not suitable habitat for anything other than certain bird species, and possibly some small mammals.

Silvopastoral practices

Cattle are intimately associated with agriculture in Nepal, and apart from fodder derived from crops and fodder trees, they are allowed to graze in nearby forest lands if the community has grazing rights. In areas adjacent to protected areas such as RCNP, there is a great temptation to graze cattle and other livestock illegally, or to cut fodder, with consequent degradation of the forest in such parks (Sharma and Shaw 1993).

Forest-based agroforestry practices

Specific agricultural practices associated with forests

A number of agricultural products (food, fruits, gums, resins, soapnut, bamboo and medicinal plants) have been collected traditionally from forests, and used by farmers or sold. There is also illegal hunting and trapping of animals such as musk deer, with a lucrative market for the musk from male deer killed at a certain time of the year. Other deer species are hunted for their meat, tiger are killed for their skins and bones (sought after for traditional Chinese medicines), as are rhinoceros for their horn.

Despite the increasing severity of penalties for those poachers who are apprehended, these practices continue to take a substantial toll of Nepal's protected wildlife. If anything is to be done to halt this illegal exploitation, it can only be achieved by measures which seek to totally change the attitude of local people towards these animals and their habitat.

Silvopastoral practices

Cold arid and subarid regions. Grazing in alpine pastures and temperate forests by seminomadic communities is considered to be an outstanding example of resource management in the upper mountain and hill regions. The livestock graze subalpine and alpine pastures (3000–4000 m elevation) in spring and summer, and as cold weather approaches they move down to graze in temperate forests (2000–3000 m elevation) during autumn and winter. The forest-derived fodder comes from conifers, birches and dwarf rhododendrons.

The livestock are the hardy yak (*Bos grunniens*) and yak–cattle hybrids (chauri) at high altitudes, and goats, sheep and buffalo at lower altitudes. These communities also grow crops such as potato, millet and barley during the very short growing season. The people who practice this system are mongoloid groups such as the Tamang, who inhabit the area in and near Langtang National Park (LNP). Such practices in protected areas like LNP have some impact on the environment, with overgrazing and cutting of trees for fuelwood being of concern. These have direct effects on wildlife, but to date these have probably not been serious inside the parks. The illegal poaching of protected animals by these people is of greater concern, despite the active efforts of the Royal Nepalese Army and the Department of National Parks and Wildlife Conservation (DNPWC) to deter and prosecute poachers.

Temperate to subtropical regions. These regions are densely populated with both humans and livestock. There are both community and individual grazing systems, mainly in subwatersheds at elevations of 1500 to 3000 m. Farmers mostly adopt a cut-and-carry system for stall feeding their stock. A similar system is used by individual farmers at 2000 to 3000 m near hill-tops and ridges, with land gradually 'claimed' from the original forests.

It can be seen that the Nepalese farmer extracts a living in a variety of ways from a country which is often inaccessible, and harsh by any standards of human existence. It is very apparent that the wildlife of Nepal is under serious pressure, as a result of loss or degradation of habitat, and illegal poaching. A range of measures can be adopted to reduce this impact, and at the same time to enhance the living standards of local people — if there is a will to do so, and the resources are allotted for their development.

Factors affecting biological diversity

It is possible to identify a number of factors which directly affect the preservation of biological diversity in Nepal, and in all Asian countries:

- overpopulation
- deforestation
- illegal hunting and trapping

There is also the potential for adverse effects due to mining and other engineering activities, pollution of the environment with human and industrial wastes, and uncontrolled tourism.

Overpopulation

The human population in Nepal continues to increase at a rate which cannot be sustained by existing agricultural systems. Most adverse effects flow from the high population, and it it will be difficult to remedy the environmental and ecological degradation which is now occurring until population growth falls. This is generally true of the whole region, which includes some of the most densely populated areas of the world. With a land area of less than one-quarter (22.9%) of the world's area, this region accounts for more than half (55.8%) of the world's population.

Deforestation

This has occurred because of the over-use of forests for fuelwood and fodder, and overgrazing of domestic stock. To a lesser extent in Nepal than in some other countries, commercial logging has also played a part. In the Terai it is common for good quality sal (*Shorea robusta*) timber to be cut illegally, with a suspicion that much is transported across the Indo–Nepalese border and sold in Bihar, India (Heinen and Kattel 1992).

In 1992, scientists in Vietnam identified an entirely new species of large mammal, a cowlike creature with the glossy coat of a horse, the agility of a goat and the horns of an antelope. It has been named *Pseudoryx nghetinhensis*. This is the first new large mammal to be discovered since a species of wild bovid — the kouprey — from northern Cambodia, southern Laos and Vietnam was described in 1937 (Vo Quy 1993). It gives emphasis to the need for much greater efforts to describe and conserve the immense biodiversity of Asian countries. The conservation of extensive tracts of Malaysian rainforests is likely to be of major importance to the continued existence of such species as the Asian elephant (*Elephas maximus*), Asian two-horned rhinoceros (*Dicerorhinus sumatrensis*), Malayan tapir (*Tapirus indicus*), wild cattle such as the gaur (*Bos gaurus*) and banteng (*B. javanicus*), serow (*Capricornis sumatraensis*), sun bear (*Helarctos malayanus*) and orangutan (*Pongo pygmaeus*) (Payne 1990).

Illegal hunting and trapping

The animals most affected by poaching in Nepal are musk deer (*Moschus chrysogaster*) in protected areas in the mountains — such as Langtang National Park (LNP) — Bengal tiger (*Panthera tigris*) and Indian rhinoceros (*Rhinoceros unicornis*) in national parks in the Terai and inner Terai — Royal Chitwan National Park (RCNP), and Bardia National Park (BNP). In other countries there are similar problems, including the trapping of species such as orangutan in Malaysia for the illegal exotic animal trade, and the snaring and trapping of Giant Panda (*Ailuropoda melanoleuca*) in China.

Battalions of the Royal Nepalese Army are stationed in a number of national parks (notably LNP and RCNP), with a major task being to deter or apprehend poachers. There are also antipoaching units within DNPWC and the Forestry Department, and penalties for poaching have recently been increased. However, poaching continues at a variable rate despite these measures to prevent it, due largely to the potential value of products such as musk and rhino horn, and the very difficult and inaccessible terrain.

Mining

Nepal has not been as affected adversely by mining and other engineering works as have some other countries in the region, but there needs to be an awareness of the way in which the environment can be severely damaged if no proper controls are in place. Key habitat can be destroyed if no assessment of environmental impact is made before approvals are given.

Tourism

Nepal's spectacular parks and reserves attract a very large number of foreign visitors, with increasing evidence that this is having adverse effects. There needs to be policy development which identifies more precisely the economic benefits and environmental impacts of nature tourism (ecotourism) in Nepal. Official foreign exchange receipts from tourism increased from $78000 in 1961–62 to $76 million in 1988 — it is the country's leading foreign exchange earner (Wells 1993). The same potential exists in many other Asian countries, with a similar need for effective controls to match the rapid development and possible adverse effects of tourism.

Remedial measures

Overpopulation

A reduction in the rate of population growth is the issue most fundamental to an improvement in the environmental and socioeconomic situations in countries like Nepal. This can only be achieved by the adoption by governments of policies which are practical, affordable, and which recognise human rights. While appropriate birth control technologies may be now available, there continue to be immense problems in using these in the societies in question. It will require a long-term process of education and extension before any substantial change occurs across most of the region. There has been sufficient progress in some places to engender hope for the future.

Deforestation

The measures currently available to attack this problem are either to prevent the continuing over-use or degradation of existing forests, or to provide alternative sources of fodder, fuel and building materials. Those who currently use the forests must be persuaded to change their behaviour. This may not always be successful. Sharma and Shaw (1993) found that farmers near RCNP could not promise to stall-feed their livestock if they were allowed greater access to the park to cut fodder, with many acknowledging that they would increase the number of animals they own in response to any new source of fodder — with consequent increases in illegal grazing.

Nonetheless, it is rational to compensate for the loss of old growth forests with new plantations of trees, whether these be for logging or for other purposes, such as for fodder and fuelwood. In Nepal and most other countries in Asia this is occurring, but much more needs to be done to develop policies which enhance the role of reforestation in the management of existing forests, and in the conservation of wildlife.

Measures taken to identify and conserve critical koala habitat are a feature of logging operations in southern Australia, with good evidence that the commercial timber industry can in fact operate economically while still preserving threatened species. This includes the use of field surveys in the prelogging phase, and postlogging koala detection surveys. Proactive management with respect to wildfire and predator control, a flexible planning system, external advice and local research are important management tools which protect individual koala populations, provide interconnectivity through the use of corridors, and prevent habitat destruction and fragmentation. There is no reason why a similar approach cannot be taken for such animals as orangutan in Malaysia and Indonesia, where logging threatens these animals.

Regulatory and punitive measures to reduce illegal cutting of trees and grazing of livestock have been of only limited value in Nepal. In many cases measures prohibit practices which were permitted before parks were gazetted, and directly interfere with the subsistence pattern of local people. In RCNP one of the main tasks of the Army is to impound trespassing livestock and present their owners for prosecution. Despite large numbers of armed guards, and substantial fines (doubled since 1988–89), there is no sign of a decline in livestock trespassing in RCNP, or in trespassing by people to cut fodder. Many soldiers are reluctant to enforce the law, due to their own culture and philosophy (Sharma and Shaw 1993).

Illegal hunting and trapping

In Nepal and all other countries there are laws prohibiting the hunting of endangered species, with varying resources allotted to the policing of these laws. In Nepal some 10% of the land area is under some form of protection, with 14 national parks and other protected areas having been created since the passage of the *National Parks and Wildlife Conservation Act 1973*. DNPWC was then formed (from an office previously under the Department of Forestry) with the power to create and manage protected areas. Despite the relatively rapid development in conservation activities, government support, and the legal protection granted in many natural areas of the country, there is human encroachment and many management problems in all of Nepal's protected areas (Heinen and Kattel 1992).

In Nepal, and in all other countries under consideration here, interactions between people and the national parks are central to any solution to conservation and preservation. Measures must be taken which lead to acceptance of national parks and other protected areas as essential elements in national development policy, with full integration in regional and local development planning, in accordance with the concept of 'conservation for development' (Sournia 1986)

Use of wildlife

There is good evidence from Africa and elsewhere that regulatory measures alone have little impact on poachers, as long as there is a good market for the product. There is also evidence that it is possible to change local attitudes to wild animals by demonstrating that a sustainable income can be derived by managing and harvesting certain species, with the direct benefits going to the community concerned. An excellent example of this is in Zimbabwe, where commercial safari hunting has been incorporated into the CAMPFIRE project (Communal Areas Management Program for Indigenous Resources), with a proportion of fees paid to safari operators by hunters being passed on to villages who 'own' the animals (Cumming 1989). A similar fee-hunting industry with non-endangered species such a sambar deer (*Cervus unicolor*) could well be successful in Asia.

Another example can be found in South America, with the captive breeding and release of the green iguana *Iguana iguana*, which is a traditional source of food in many areas from Mexico to Paraguay. Reforestation is an integral part of the management models which have been put in place (Werner 1991a, b).

The concept of putting a monetary value on wildlife as part of ensuring the conservation and management of certain species is not new. But the potential has not been fully explored in much of Asia, with the possible exception of ecotourism. A musk deer farming project was started by DNPWC in Nepal in 1992. The project seeks to exploit the monetary value of musk, while ensuring that the Himalayan musk deer is not poached to extinction. This is a model for other such activities in Asia, with the potential to combine a new economic activity with the conservation of endangered or threatened animals.

The same potential to examine the possible use of wildlife species as alternatives to traditional livestock exists elsewhere in Asia. For this to occur there needs to be a period of research and development, with pilot studies followed by a process of education and government support when a possible new industry is identified. For example, banteng cattle could well prove to be more effective meat producers than are the cattle currently used (McCool 1992), and various deer species can be farmed for meat, velvet antler and other byproducts used in traditional medicine. There are in fact about 500 000 deer on farms in China, and other countries like Malaysia are following suit with commercial deer farming.

There are other examples which can be listed, such as the farming of crocodiles in Irian Jaya, and the ranching of two species of turtles (hawksbill [*Eretmochelys imbricata*] and green turtle [*Chelonia mydas*]) in Bali and west Java, which give emphasis to the range of possible new initiatives in the conservation and use of wildlife species across Asia. A recent report by Ramsay (1994) on the commercial use of wild animals in Australia provides good evidence of the range of opportunities for the development of new inititaives which have been embraced in that country.

Ecotourism

There is tremendous potential in Asia for the development of tourism based on natural and cultural resources. It is often difficult to separate these two elements when attracting tourists from industrial countries, just as it is easy to incur negative effects from poorly planned and executed ecotourism activities. Nonetheless, there is an opportunity to better use the wilderness areas and wildlife of Asia in accordance with 'conservation for development'.

A National Ecotourism Strategy has been developed in Australia. It aims to establish a national framework to guide the planning, development and management of tourism in natural environments, while maintaining the integrity and quality of these environments (Australian Department of Tourism 1994).

Conclusion

The loss of biodiversity in Asia is occurring at an alarming rate. Species such as the Asian elephant, tiger (Bengal, Sumatran, South China, North East China), rhinoceros (Indian, Javan and Sumatran) and orangutan may soon no longer exist in the wild, or only in small numbers in protected areas. As most Asian countries now enter an era of unprecedented development, there are both the opportunities and the challenges involved in doing something about this. As long as human populations continue to increase at the current rate, this is going to be a difficult exercise for governments and international agencies concerned with wildlife conservation. The potential use of wildlife species, including the development of strong ecotourism industries, should not be ignored during this process.

Acknowledgments

I am grateful for the information supplied by ACIAR officers in a number of countries, and express special appreciation for the cooperation and support from my friends in HMG Department of National Parks and Wildlife Conservation in Nepal.

References

Australia, Department of Tourism. 1994. National Ecotourism Strategy. Canberra, ACT, Australian Department of Tourism.

Cumming, D.H.M. 1989. Commercial and safari hunting in Zimbabwe. In: Hudson, R.J., Drew, K.R. and L.M. Baskin, L.M., ed., Wildlife production systems. Economic utilisation of wild ungulates. Cambridge, Cambridge University Press.

Dixon, J.A. and Sherman, P.B. 1990. Economics of protected areas. A new look at benefits and costs. London, Earthscan Publications Ltd.

Heinen, J.T. and Kattel, B. 1992. Parks, people, and conservation: A review of management issues in Nepal's protected areas. Population and Environment, 14, 49–84.

Lai, C.K. 1992. Agroforestry in support of animal production in Asia and the Pacific region. RAPA Publication 1992/12. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.

McCool, C. 1992. Buffalo and Bali cattle—exploiting their reproductive behaviour and physiology. Tropical Animal Health and Production, 24, 165–171.

Panday, K.K. 1982. Fodder trees and tree fodder in Nepal. Swiss Federal Institute of Forestry. Switzerland. Cited by K.G. Tejwani and Chun K. Lai, Asia-Pacific Agroforestry Profiles. Agroforestry Systems Research and Development in the Asia and Pacific Region (GCP/RAS/133/JPN), 1992.

Pande, R.S. 1992. Need for agro-silviculture to meet the demands of livestock feed in Nepal. In: Lai, C.K., ed., Agroforestry in support of animal production in Asia and the Pacific region. RAPA Publication 1992/12. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific, 97–108.

Payne, J. 1990. Rarity and extinctions of large mammals in Malaysian rainforests. Proceedings of the International Conference on Tropical Biodiversity, 12–16 June 1990, Kuala Lumpur, Malaysia, 310–320.

Ramsay, B.J. 1994. Commercial use of wild animals. Bureau of Resource Sciences. Canberra, ACT, Australian Government Publishing Service.

Sharma, U.R. and Shaw, W.W. 1993. Role of Nepal's Royal Chitwan National Park in meeting the grazing and fodder needs of local people. Environmental Conservation, 20, 139–142.

Sournia, G. 1986. Integration of national parks and faunal reserves in the economy of developing countries. Parks, 11, 8–9.

Tejwani, K.G. and Lai, C.K. 1992. Asia-Pacific agroforestry profiles. Agroforestry Systems Research and Development in the Asia and Pacific Region (GCP/RAS/133/JPN).

Tuladhar, A.R. 1990. Agroforestry in Nepal. Expert Consultation on Agroforestry in the Asia-Pacific Region. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific, 9.

Vo Quy 1993. Conservation of biodiversity and forest resources in Vietnam. University of Hanoi, 10.

Wells, M.P. 1993. Neglect of biological riches: the economics of nature tourism in Nepal. Biodiversity and Conservation, 2, 445–464.

Werner, D.I. 1991a. Iguana management: a model for conservation through sustainable use. In: Renecker, L.A. and Hudson, R.J., ed., Wildlife production: conservation and sustainable development. Fairbanks, Alaska, USA, University of Alaska, AFES Miscellaneous Publication 91-6, 36–39.

— 1991b. The rational use of iguanas. In: Robinson, J.G. and Redford, K.H., ed., Neotropical wildlife use and conservation. The University of Chicago Press, 181–201.

Agroforestry, Resettlement and Shifting Cultivation

A. Sabrani and Y. Saepudin*

Abstract

Agroforestry modes and some factors relevant to the development of resettlement for shifting cultivators were studied. Analysis however is directed to sustain interaction between livestock and agroforestry to improve livestock production systems as well as tree crops and environmental aspects. The changes in shifting agriculture were also discussed to give a better understanding of shifting cultivators and the importance of the symbiotic relationship between traditional and modern sectors of the Indonesian economy.

FIVE major agricultural production systems are practiced in Indonesia:

- shifting agriculture as practiced by local tribes who periodically move;
- open areas fed naturally by rain as well as by irrigation systems;
- multistrata cropping which allows interaction between trees, food crops and animals;
- plantation systems developed for specific market demand, such as rubber, palm oil, coconut, coffee, cocoa and orchids; and
- timber tree farming (industrial forest) which is a newly developed system for producing wood and pulp.

Within these systems livestock production can be developed as a sideline component; as an integrated farming component which improves biomass recycling; or as a major farm activity. These systems occur in both the traditional and modern sectors of agriculture.

As the need to produce tree and food crops increases, agricultural activities move closer to the forest. Consideration should be taken to ensure that environmental and regional development concerns are not in conflict.

Forestry and agriculture are strong competitors for land resources: often the best land for forestry is also the best land for agriculture. Forest area in developing countries declined from 2373 million ha to 2258 million ha within 10 years (1974–84); pasture area increased from 1896 million ha to 1904 million ha, and crop area expanded from 66 million ha to 78 million ha over the same period (FAO 1986). This may be overcome to some extent by integrating forestry and agriculture at the regional level.

In Indonesia over the same period (1974–84); crop area increased from 5.2 million ha to 5.3 million ha, forest area fell from 122.1 million ha to 121.8 million ha, and area under pasture fell from 12.2 million ha to 11.9 million ha.

This paper explores the possibility of improving agricultural and forestry systems, in the context of shifting agriculture and agroforestry. The underlying hypothesis of this paper is that increasing human pressure on land use, combined with increased concerns about the environment justifies agroforestry intervention to remodel shifting agriculture.

Shifting Agriculture

Approximately 37 million ha of land in Indonesia is subject to shifting agriculture (FAO 1978). Shifting cultivation is a system of primitive agriculture which involves total land clearing (tree cutting, shrub clearing) and burning in preparation for planting. The land is planted with rice and secondary crops for home consumption. Cultivators also gather varieties of forest products and wild animals. The crop area is entirely open and subject to environmental degradation. After 5–10 years soil fertility has declined and

* Research Institute for Animal Production, Bogor, Indonesia.

cultivators move to a new location and repeat the cycle.

Traders in villages close to forests make contact with shifting cultivators to develop trading or barter for forest products.

Livestock is raised in shifting agriculture for subsistence needs and as a means of saving. Some cultivators consider livestock an indicator of social status and prestige. Hardy species of poultry and pigs usually predominate. In some regions, cattle and buffalo are more common. Partial confinement of livestock is practiced. Crop wastes, agricultural byproducts and forage are fed to animals.

There are three groups of shifting cultivators: those that cultivate within the primary forest; those that cultivate secondary (shrub) forest; and those that cultivate open areas such as those areas dominated by *Imperata cylindrica*. Some dwellings are mobile and some are permanent.

Shifting agriculture is a transitional form of agriculture between swidden and permanent agriculture. Changes from shifting to permanent agriculture occurred with the development of the early plantations. Some shifting cultivators planted tree crops such as rubber and fruit, and also maintained food crop production for home consumption. In Sumatra and Kalimantan, shifting cultivators developed permanent rubber, coffee, coconut and pepper plantations (Pelzer 1978). These tree crops are commercial crops in both the domestic and international markets. This change from shifting to permanent agriculture illustrated that shifting agriculture can be remodeled to commercial crop cultivation provided there is economic infrastructure, and markets are available. With improved technology and the availability of infrastructure, resettled shifting cultivators can plant tree and food crops, as well as keep animals.

Indonesia's Department of Transmigration incorporates shifting cultivators in resettlement programs. This brings traditional shifting cultivators in contact with aspects of the modern market economy. Income flows from the modern sector to the traditional sector. These two sectors are driven by different motivations. The traditional sector is home-consumption and security orientated, and the modern sector is directed to profit maximisation. This dualistic economy occurs in most developing countries (Boecke 1983).

The major problem encountered in resettling shifting cultivators is how to encourage the evolution of the social system so that it responds to the signals of the modern economy.

The welfare of shifting cultivators should be improved by including them in resettlement programs. At both the sector and regional level, positive interaction between shifting cultivators and institutions dealing with resettlement should be developed. Gradual social changes should be encouraged. The relationship of shifting cultivators to the forest should be maintained until necessary infrastructure is established.

The problems faced by shifting cultivators are thus external and internal in nature. External factors include the lack of economic infrastructure, technology, incentives and markets. Internal factors are attitudes and values. A thorough understanding of these cultural factors is necessary for the successful implementation of resettlement programs, it should be the centre of program implementation.

Agroforestry, Resettlement and Livestock

Indonesian landuse is dominated by flat or lowland annual cropping. Upland agriculture is dominated by tree cropping and fodder production. Between these extremes there are a variety of landuse patterns. The introduction of livestock and fodder crops in the tree-cropping upland areas improves the efficiency of solar energy conversion to ground vegetation. Without livestock, the fodder, tree legumes and other biomass which are available in upland agriculture have no value to the farmer. (UWRP 1992; YDADP 1993; IDRC–AARD 1993).

Therefore, crucial components in the development of agroforestry for production, environmental protection and soil conservation include the choice of location, species of plant, animal, technology and the farmer who will participate. Economies of scale can be achieved by area zoning and farmer groupings to form production units. This will assist technology transfer and marketing.

A survey of transmigration and resettlement showed that food-crop productivity declined over time. This was particularly true of rice, corn and cassava. To improve this condition, the use of manure, mulch, fertilizer and crop rotation is encouraged.

Total land clearing in resettlement areas should be avoided and replaced by the development of agroforestry. A program of gradual tree cutting to sustain agricultural production and environmental quality should be introduced in resettlement programs.

Tree cutting can be completed if the planned tree crops develop. The replacement of the forest with introduced tree crops should follow a gradual transitional pattern. The existence of tree crops and livestock in a multicropping system improves labour use and flexibility, and reduces the cost of managing tree crops. Tree crops and livestock are important in resettlement areas, they provide an income net if food crops fail. (Odelman 1978). Trees and livestock are risk absorbers (Dasmann et al. 1973). The percentage contribution of livestock in various tree cropping–livestock systems to farmer income ranged from 5 to 75% (Table 1). The percentage contribution of sheep

Table 1. Estimates of the relative net-return in various tree cropping and livestock production systems.

System	% contribution of animal in tree–animal system income
Palm oil– sheep (Indonesia)	5–10
Rubber– sheep (Indonesia)	15–20
Coconut– cattle (Bali)	75
Coconut– sheep (Philippines)	50

Source: Anonymous, 1990.

to income in a palm oil system ranged from 5–10%; sheep in a rubber system, 15–20%; cattle in a coconut system, 75%; and sheep in a coconut system, 50%.

Under multiple-tree cropping in Central Java the presence of livestock in the system improved farmer income (Table 2).

In establishing agroforestry for resettlement, it has to be specified which trees will become the main tree crop, which ones will be inserting plants and which ones will be partitioning or fencing plants (Hernanto 1993). This is important for the development of permanent plants and seasonal plants.

The next section discusses some agroforestry models which may be useful in resettling shifting cultivators.

Food crop intercropping within forested areas

Since 1986 the Department of Forestry in Java has implemented a model which allows food crop and animal production in young forest areas (FAO 1994). In this model, forest trees are the main trees while the others are supporting. The opportunity to join this program is given to farmers surrounding the forest area, and to the landless. They are responsible for planting forest-tree seedlings and caring for them. Among the rows of main forest trees, food crops, tree legumes, or grass can be grown. The total cost of tree planting, care and maintenance is relatively low and farmers can produce food and feed as well as firewood. Farmer income is estimated to be increased by 20%, 70% of this due to the tree component (Hernanto 1993).

Problems faced in this program include: lack of farmer group action; inadequate extension and training; and lack of coordinated marketing for the yield produced.

Amarasi agroforestry model

This model was developed in the semi-arid Amarasi area of Timor Island.

Before the model was introduced, farmers of this area practiced shifting cultivation. They moved between plots of land as soil fertility declined. The aim of the model is to establish high density plantings of the tree legume lamtoro (*Leucaena leucocephala*) on dry land. Maize and legumes are planted in rows between lamtoro. The lamtoro plantation creates a good microenvironment to support maize and other food crops (Jones 1983).

Lamtoro is the main tree. Other tree crops such as coconut, banana, jack fruit, papaya and grass are supporting plants. The inserting trees may be mahoni and teak.

The model is expected to improve animal carrying capacity from 0.5 to 3 au/ha. In terms of cattle fattening, the model will support 5 to 7 head of cattle/2 ha/year, and produce income of between Rp 600000 and Rp 1000000 per year (Surata and Sutarjo 1993).

There are four elements in the Amarasi model of agroforestry:

Table 2. Farmers' income per year in various models of agroforestry.

Component	Agrosilvopasture (Rp)	Agrosilviculture (Rp)	Farmers' model (Rp)
Food crops	181130	188 656	
Tree crops	38030	46951	155 470
Animals	255 535	0000	
Total	474 695	235 607	155 470

Source: Sumarsono et.al 1993.

- Lamtoro trees in thickets to achieve total shade for 85% of the land holding.
- One-third of shaded lamtoro area is cleared each year and left on the field as mulch for growing maize and other crops.
- The remaining two-thirds of the area is left fallow to provide feed for cattle. Rotation is made either every year or two years.
- The gradual introduction of bananas, papayas, coconut and other tree crops to moister parts of the land on which lamtoro is growing, as moisture regimes improve (Metzner 1983).

Plantation agroforestry

The main trees of this model are plantation crops such as rubber, palm oil, coffee, cocoa, coconut and other climbing crops. Fodder shrubs and trees can be integrated into the system to improve land carrying capacity. Nitis et al. (1990) suggested that the integration can be developed in the form of intercropping, alley cropping, shade integration, climber integration, living fences, and feed bank integration. Depending on the intensity of integration, carrying capacity can be increased by 5 to 81%.

Industrial agroforestry

This system is developed to produce fast growing trees surrounding forest boundaries, for wood and pulp production. The model has been developed in anticipation of the increasing industrial demand for wood and pulp, which cannot be supplied by natural forest alone.

Feed resource under the trees, and leaves, are potentially available for ruminant production. Development of related ground vegetation for feed should be encouraged to improve total land productivity.

Livestock–tree crops in fragile uplands

This model has been developed in fragile upland agriculture in the Yogyakarta area. The intention is to increase soil conservation by the planting of grass along terraces, with tree legumes and trees as fodder. This will enable the intensification of livestock and the development of fodder as well as environmental improvement. The livestock will increase the economic value of the fodder and improve soil by manure application.

The development of living fences of trees along rugged terraces helps reduce soil erosion (YPADP 1993).

Conclusions

To develop sustainable agroforestry and resettlement for shifting cultivators, three dimensions of planning are identified: the farm level; the sector or subsector level; and the regional level. Farm level planning should cover sustainable production systems, reduced risk, and increased nutrient cycling. Planning should be directed at farmer training, group formation, and extension for proper technology transfer. The sector or subsector levels should involve policies on commodities, market price incentives and technology. The regional level is reponsible for coordinating the development of agroforestry and resettlement programs which address environmental quality and land use. This is related to a number of factors such as land suitability, climate, socioeconomic conditions and regional development needs.

Sustainable agroforestry and resettlement must be set in a longer-run policy framework at all levels which involves the entire rural and regional economy.

Incentives through higher product prices should be maintained, especially in remote areas of resettlement. This policy will improve the economic performance of agroforestry and resettlement programs in generating capital assets and the adoption of technology.

The modern sector of the economy should be encouraged to develop a symbiotic relationship with the traditional sector in agroforestry and resettlement programs.

References

Anonynous 1990.

Boecke, J.H. 1983. Prakapitalisme di Asia. Sinar Harapan, Jakarta.

Dasmann, R.F., Milton, J.P. and Freeman, P.H. 1973. Ecological principals for economic development. New York, John Wiley and Sons Ltd, 73–108.

FAO 1978. Shifting cultivation. Forest news for Asia and the Pacific. Bangkok, Thailand, FAO Regional Office for Asia and the Far East.

— 1986. Production yearbook, 40. Rome, FAO.

— 1994. The social forestry program since 1986. FAO, Rome, Newsletter of the Asia Pacific Agro-forestry Network No. 6/7, February.

Hernanto, H. M. 1993. Pengembangan agro-forestry disekitar hutan sebagai upaya pengentasan kemiskinan. Makalah pada Seminar Nasional Masyarakat Konservasi Tanah dan Air di Indonesia. Yogyakarta, 27–28 Oktober 1993.

IDRC–AARD 1993. Annual report of crop–livestock research project. IDRC–AARD, Bogor.

Jones, P.H. 1983. Lamtoro and the Amarasi model from Timor. Bulletin of Indonesian Economic Studies, 19(3), 106–112.

Metzner, J. 1983. Innovations in agriculture incorporating traditional production methods: the case of Amarasi (Timor). Bulletin of Indonesian Economic Studies, 19(3), 94–105.

Nitis, I.M., Putra , S. and Sukanten, W. 1990. Fitting forage into intensive plantation crop system in Bali. Paper presented at the ACIAR Workshop on Forage for Plantation Crops, Denpasar, Indonesia, June 1990.

Oldelman, R.A.A. 1978. Blue print for a new tropical agro-forestry tradition. Proceedings of the 50th Tropische Land bouwdag, Amsterdam 1978, 25–34.
Pelzer, K.J. 1978. Swidden cultivation in Southeast Asia. Historical, ecological and economic perspectives. In: Kunstadter, P., ed., Farmers in the forest. Honolulu, East West Center, 271–286.
Sumarsono, D.R. and Purbayanti, E.D. 1993. Model pemanpaatan lahan agro-silvo pastura di Jawa Tengah. Prosiding Lokakarya Nasional Agro-forestry. Bogor, Agustus 1993, 151.
Surata, I.K. and Sutarjo. 1993. Model agro-forestry lahan savana di Pulau Timor. Prosiding Lokakarya Nasional Agro-forestry. Bogor, Agustus 1993, 156.
UWRP 1992. Upland watershed research project report. Salatiga, UWRP.
YPADP 1993. Yogyakarta up land area development project yearly report 1993. Yogyakarta, YPADP.

Strategies to Develop Sustainable Livestock on Marginal Land

S. Sukmana, A. Abdurachman and A. Syarifuddin Karama*

Abstract

Marginal land may be formed either naturally or by human activities. Human activities have created millions of hectares of degraded land in many watersheds over the country. The Upland Agriculture and Conservation Project (UACP) implemented in the Jratunseluna (central Java) and Brantas (east Java) watersheds from 1984 through 1993 was a government attempt to rehabilitate the degraded watersheds. The goal of the UACP was to increase farm production and income while minimising soil erosion and promoting soil conservation. This paper refers mainly to research results obtained from farming systems research activities conducted in the UACP target areas.

Introduction of high yielding grasses and shrub legumes to stabilise terraces improved animal carrying capacity from 1 animal unit (au) to 4–6 au/ha and made farm labour more efficient. Livestock development enhanced the development of perennial crops, and this increased farmer income and improved the hydrological function of the watershed. Farmers are keen to invest capital in livestock raising; however, current development of livestock is constrained by availability of capital.

Based on those findings and other information, strategies to develop livestock on marginal land are suggested.

SINCE 1984 Indonesia has been self-sufficient in rice — an achievement gained after two decades of attempts to increase rice production. Lowland rice cultivated on irrigated rice fields and tidal swamps contributes the major proportion of national rice production. The land suitable for lowland rice production is limited, and the demand for rice continues to increase with the growing population. At the same time, more land for building houses, roads etc. is needed. Thousands of hectares of rice fields each year are lost from agricultural production. Tidal swamps, which are abundant, may offer greater potential for rice production in the future.

Increases in population have caused more upland areas to be cultivated for annual food crops. Inappropriate land use and poor management have caused severe soil erosion and have degraded land over many watersheds.

The extent of degraded land in March 1990 was 6.8 million ha, of which 4.9 million ha (72%) were outside the forest and 1.9 million ha (28%), inside the forest (Biro Pusat Statistik 1992).

The Upland Agriculture and Conservation Project (UACP) implemented in the upper watersheds of the Jratunseluna (central Java) and the Brantas (east Java) from 1984 to 1993 was one attempt to rehabilitate degraded land through the improvement of existing farming systems and soil conservation. The goal of the project was to increase farm production and incomes while minimising soil erosion and promoting soil conservation. This paper refers mainly to research results obtained from farming systems research activities conducted in the UACP target areas. We suggest strategies for livestock development on marginal, critical land, particularly in the upper watershed areas. The term marginal land used in this paper is identical to the term critical land used by the Ministry of Forestry.

General Description of the Area

Soil and climate

The total area of the Jratunseluna and the Brantas watersheds is about 0.7 million and 1.1 million ha respectively (Suwardjo and Saepudin 1988). In the

* Center for Soil and Agroclimate Research, Bogor, Indonesia 16610.

Jratunseluna upper watershed the major soils are inceptisols, alfisols, vertisols and entisols, occupying about 127400 ha (70% of the surveyed area); about 35000 ha (20% of the surveyed area) contains shallow soil (Soekardi 1991).

In the Brantas upper watershed the major soils are mollisols, alfisols and andisols, occupying about 114600 ha (64% of the surveyed area); in about 46800 ha (26% of the surveyed area) the soils are shallow. These areas are mostly hilly with slopes greater than 15% and altitude varying from 200 to 800 m above sea level.

Rainfall in these areas varies from 1500 to 3500 mm/year, with wet seasons fall from October through April.

Soil erosion potential is high due to the high rainfall intensity and steep slopes. As much soil erosion as 134 t/ha/year was observed on land planted to annual food crops without soil conservation being practiced, while erosion on land treated with bench terraces was generally less than 10 t/ha/year (UACP-FSR 1992).

The lands are in general only marginally suitable for annual food crops because of soil erosion risk.

Farming Systems

Average size of landholdings in the Jratunseluna and the Brantas watershed areas is about 1 ha per farm household (Levine 1988; 1989; Saragih et al. 1993). The greater portion of this land is used for dryland farming. The rest consists of home garden and rainfed 'sawah' (rainfall-dependent flooded rice cultivation).

As in most upland areas, smallholders are subsistence farmers, they cultivate annual food crops regardless of the steepness of land slopes. Upland rice or maize is the staple crop, while cassava and grain legumes, such as peanut, soybean etc., are secondary crops. Perennial crops (tree crops), both horticultural and industrial, as well as livestock are usually involved in the farming systems. The income contribution of annual food crops, tree crops, livestock, forest products and off-farm work to total farm income was 32%, 18%, 22%, 9% and 19% respectively (Saragih et al. 1993).

The main soil conservation technique is bench terracing. This technique has been promoted since 1976 by the government through its Regreening and Reforestation Program.

Prospect of Livestock Development

As long as subsistence farmers on marginal and critical uplands continue the cultivation of annual food crops, sustainability of production is questionable. Even though, through the introduction of improved technologies, annual food crop yields could be almost doubled (Abdurachman et al. 1992), Saragih et al. (1993) found that this increase lasted only two years, the period over which farmers received the farm input subsidy (seeds, fertilizers, pesticides).

Livestock plays a very important role in improving marginal or critical uplands. It is an important source of organic matter, which is urgently required. One head of cattle can produce 9 to 17 t of manure per year.

In the UACP areas the application of livestock manure is common, but the rate is usually low, 0.6 to 4 t/ha/year (Sabrani et al. 1989; Saragih et al. 1993). A rate of at least 10 t/ha/year is required to have a significant effect (Fagi et al. 1988; Toha and Abdurachman 1991).

Farmers who raise livestock grow grass and shrub legumes on bench terrace edges. This stabilises terraces and provides feed (Hermawan and Prasetyo 1991). Farmers who do not raise livestock are reluctant to do this because they do not obtain an immediate benefit.

Vegetative soil conservation practices such as the establishment of hedgerow crops of grass or shrub legume species in either alley cropping systems or existing bench terraced lands is being promoted. This technique is effective in terms of soil erosion control (Sukmana and Suwardjo 1993) and gives immediate benefit to farmers if they raise livestock.

In the UACP areas elephant grass (*Pennisetum purpureum*) is the most preferable (Hermawan and Prasetyo 1991). The yield is higher than other grass species, except king grass (Table 1). One hectare of land with 2100 m of total hedgerow (see Table 2 or 3) can produce as much as 48 636 kg/year or 133 kg/day elephant grass, sufficient to feed four head of cattle. The livestock carrying capacity of 1 ha of land treated with hedgerow crops will depend on the slope, which determines the total length of the hedgerow crop and the yield (kg/m hedgerow) of grass planted. Lubis et al. (1991) reported that the introduction of elephant grass planted as hedgerows on terrace lips of 1 ha of land with a slope of 15–30% can carry 4–6 head of cattle. Having fodder crop(s) available on the farm field reduces the amount of farm labour required for feed collection by 46–54% (Hermawan and Prasetyo 1991). It also enables the farmer to develop cattle fattening.

With cattle fattening the cattle manure can be collected and better managed. The manure produced by 4–6 head of cattle (about 50–80 t/year) can, through proper management, support horticulture development in these areas.

In general, farmers in UACP areas own only 1 to 3 head of cattle or buffalo (Harker and Gnagey 1993), but they would be keen to invest in more if finance were available (Londhe et al. 1992).

Table 1. Grasses and shrub legume production planted as hedgerow crop.

Hedgerow crop	Fresh forage production (kg/100m hedgerow/year)
King grass (*Pennisetum purpuroides*)	2831
Elephant grass (*Pennisetum purpureum*)	2316
Setaria grass (*Setaria sphacelata*)	1763
Kongo grass (*Brachiaria ruziziensis*)	1543
Bebe grass (*Brachiaria brizantha*)	1413
Gliricidia maculata	1430

Table 2. Surface distance and total length of hedgerows on 1 ha (100 m × 100 m) that can be planted to grasses and/or shrub legumes. Vertical interval = 1.25 m.

Land slope (%)	Surface distance (m)	Total hedgerows	Total length of hedgerows (m)
3–5	41.7–25	3–5	300–500
6–10	20.9–12.6	6–9	600–900
11–15	11.4–8.4	9–13	900–1300
16–20	7.9–6.4	14–17	1300–1700
21–25	6.1–5.1	17–21	1700–2100
26–30	5–4.3	21–24	2100–2400
31–35	4.2–3.8	25–27	2500–2700
36–40	3.7–3.4	28–30	2800–3000

Table 3. Surface distance and total length of hedgerows on 1 ha (100 m × 100 m) that can be planted to grasses and/or shrub legumes. Vertical interval = 1 m.

Land slope (%)	Surface distance (m)	Total hedgerows	Total length of hedgerows (m)
3–5	33.3–20	4–6	400–600
6–10	16.7–10	7–11	700–1100
11–15	9.1–6.7	12–16	1200–1600
16–20	6.3–5.1	17–21	1700–2100
21–25	4.9–4.1	21–25	2100–2500
26–30	4–3.5	26–29	2600–2900
31–35	3.4–3	30–34	3000–3400
36–40	2.9–2.7	35–38	3500–3800

Livestock as well as horticulture is seen as an important factor in improving farmers' income and the nutritional status of the population and in alleviating poverty. In the UACP areas, during the lifetime of the project, technologies to develop these commodities have been verified onfarm, farmers' skills were improved through involvement in onfarm trials and training, and farmer groups were encouraged.

The above information indicates that the upper watersheds of the Jratunseluna and the Brantas have potential for the development of livestock.

'Agribisnis' and 'Agroindustri'

To improve farmer income and standard of living agricultural activities should be market-demand oriented, which in Indonesian terminology is known as 'agribisnis' (agriculture business) and 'agroindustri' (agriculture industry).

As farmer's landholding in the upper watersheds are generally small and farming systems relatively traditional, cooperation among farmers is required to achieve continuity in supply of farm products. Also needed is the participation of private and/or state enterprise to provide capital, processing and marketing, while the involvement of relevant institutions is needed to improve farmers' skills and provide technical guidance, so that the quality as well as the quantity of farm products will meet market requirements.

Upper watershed management is currently the responsibilty of Biro Bina Kependudukan dan Lingkungan Hidup (BKLH) (Bureau of Population and Environment) and the Bureau of Agriculture and Forestry through Program Inpres Penghijauan (President Instruction for Regreening Program). To improve management the establishment of a special, integrated (farmer–government–enterpriser) program is needed.

The objectives of an 'agribisnis' systems program are:

- In the short term, to discover sources of new economic growth through livestock and horticulture development and the promotion of partnership between farmers and enterprises.
- In the medium term, to promote development through improvements in land resources, human resources, and infrastructure.
- In the long term, to improve farmers' incomes and prosperity, while maintaining the sustainability of the environment.

Organisational Structure

To develop livestock and horticulture in the upper watersheds through agribisnis systems under the Regreening Program the organisational structure of the participants needs to be determined. The development activity is carried out by a multidisciplinary and interinstitution team composed of government, farmers and private sector (Fig. 1).

The Bureau of Population and Environment has responsibility for the overall activity and serves as coordinator. The Provincial Development Planning Board, assisted by the Agency for Agricultural Research and Development (AARD), Agency for Forest Research Development (AFRD) and Center for Land Rehabilitation and Soil Conservation, prepares plans and monitors activities.

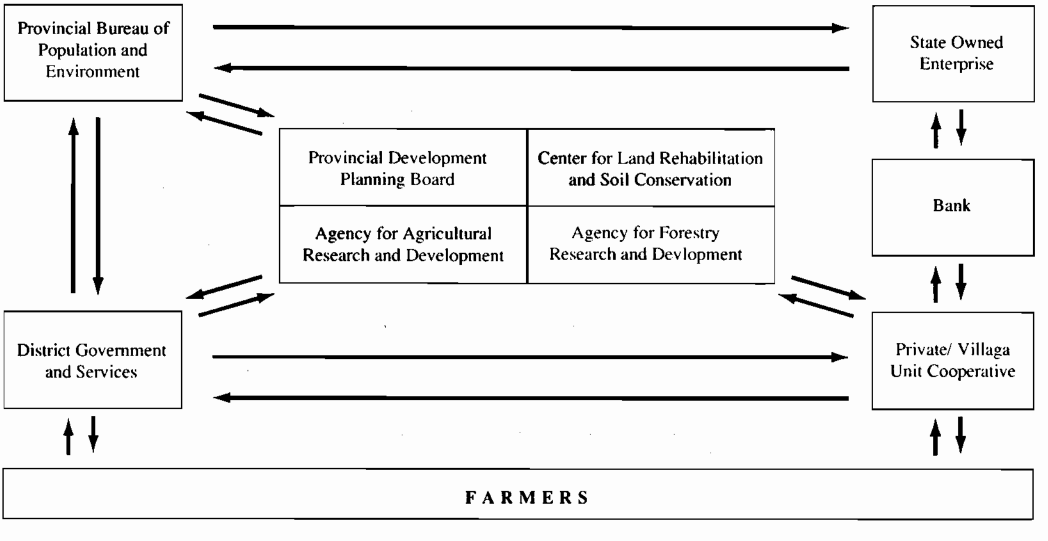

Fig. 1. Organisational structure to promote livestock development with agribisnis.

AARD is responsible for, and supervises, field activities, and works with entrepreneurs to assist in the dissemination of technology.

District governments, together with AARD and AFRD, implement the subsidy provided to farmer groups.

State owned enterprises provide funds and channel them to state owned banks for on-lending to the private enterprise or village unit cooperatives for the purchase of farm inputs.

The private enterprise or village unit cooperative is expected to play a role in marketing farm products.

Alternative Models

The model applied to develop livestock with agribisnis should be based primarily on information about the existing condition of the livestock business of the farmer. The alternative models suggested (I–V) indicate where to apply and who provides funding.

Model	Status of livestock business
I	Under developed
II	Ready potential, e.g. for cattle fattening, but farmers are not so familiar with this type of business.
III	Farmers are familiar with the type of business being developed. In this site the project helps the farmer to increase efficiency and added value.
IV	Developing stage.
V	Advanced stage.

The funds required to implement agribisnis in the Regreening Program is expected to be provided by the Project; state owned enterprises; and private enterprises or the village unit cooperative. Funds provided by government are revolving subsidies, while funds provided by state owned enterprises, private enterprises or village unit cooperative are under credit or sharing arrangements. Table 4 shows funding for each farm component of the suggested models.

Procedures

- Identification and organisation of participants. The participants, organisational structure and function are described earlier.
- Site selection. The site selection is based on the information provided by local government, and must be agreeable to all parties participating in the project. A commercial site needs at least 500 ha. This site is divided into four subsites, in which technology packaging and implementation is carried out consecutively in year 1, year 2, year 3 and year 4 (see Table 5). This is done to give an opportunity to improve the technology package and to solve difficulties that may be experienced during technology implementation on the advanced site(s).
- Diagnostic survey. After the site is selected a survey is carried out to diagnose problems related to crop and livestock production. The problems may be soil, agronomic practices, pest, farmer knowledge and skill, management, market etc. The status of the existing livestock business is also identified and characterised. This survey is carried out by a multidisciplinary team composed of soil, livestock, horticulture and socioeconomic researchers. The

Table 4. Source of funding for alternative models.

Component	Model I	Model II	Model III	Model IV	Model V
Yearling cattle	Government	Private	Private	Private	Private
Feed concentrate	Private	Government	Private	Government	Farmer
Plant material	Government	Government	Government	Government	Government
Stable	Government	Government	Government	Farmer	Farmer
Soil conservation structure	Government	Government	Government	Government	Government
Transportation	Private	Private	Private	Private	Private
Supervision	Government	Government	Government	Government	Government
Insurance	Government	Private	Private	Private	Private
Planning	Government	Government	Government	Government	Government
Project administration	Government	Government	Government	Government	Government

Table 5. Stage of implementation of livestock and horticulture agribisnis in upper watershed. Target area: 500 ha.

Year	Subsite I	Subsite II	Subsite III	Subsite IV
I	1,2,3,4a,5,6	1,2	1,2	1,2
II	4a+b,5,6	3,4a,5,6		
III	4a+b,5,6	4a+b,5,6	3,4a,5,6	
IV	4a+b,5,6	4a+b,5,6	4a+b,5,6	3,4a,5,6
V	4a+b,5,6	4a+b,5,6	4a+b,5,6	4a+b,5,6

1 = Organising.

2 = Data organisation.

3 = Technology.

4 = Technology implementation (a: livestock; b: horticulture).

5 = Supervision.

6 = Evaluation and reporting.

results of this survey are used to select the model and determine the technologies which will be applied.

- Technology packaging. The packaging of technology is based on verified technologies and results of the diagnostic survey. The farming system is focused on livestock development, fodder crops, followed by development of horticultural commodities with high economic value.
- Implementation of technology and supervision. Planting of grass and shrub legumes on terrace lips should be done as early as possible to provide feed and stabilise terraces. The placement of cattle provided by governement or private sector will follow once the feed is available. The cattle manure must be managed properly and applied to fertilise the hedgerow crops (fodder) and for horticulture development.
- Supervision and guidance to improve farmer knowledge and skill should be regular.
- Evaluation and reporting. The success of livestock as well as horticulture development is characterised by an increase in farmer income and by erosion control. Qualitative evaluation may be done by conducting a field day, while quantitative evaluation may be done by employing 'before-after approach' or a 'zero-one relationship approach'.

Reporting consists of: diagnostic and baseline survey report; progress reports: monthly, quarterly and annually: and a final report, which is useful for other parties wishing to conduct a similar project.

References

Abdurachman, A., Prawiradiputra, B.R., Toha, H.M., French, J.H. and Nataatmaja, H. 1992. Penelitian usahatani konservasi lahan kering di DAS Brantas dan Jratunseluna:Program 1992–1993. Prosiding Seminar Penelitian dan Pengembangan Sistem Usahatani Konservasi di Lahan Kering DAS Jratunseluna dan Brantas. Cipayung, 10–11 Februari 1992. P3HTA. Badan Litbang Pertanian, 249–265.

Biro Pusat Statistik 1992. Statistik Indonesia 1992 (Indonesian Statistical Yearbook).

Fagi, A.M., Ismail, I.G., Kusnadi, U., Suwardjo, H. and Bagyo, Al Sri 1988. Penelitian sistem usahatani di daerah aliran sungai. Risalah Lokakarya Hasil Penelitian Pertanian Lahan Kering dan Konservasi di Daerah Aliran Sungai, Salatiga 14 Maret 1988. P3HTA. Badan Litbang Pertanian, 1–23.

Harker, B.R. and Gnagey, R.W. 1993. Effects of the upland agriculture and conservation project on farmers' incomes. Lokakarya Nasional Pembangunan Daerah dalam Rangka Pengelolaan Usahatani Lahan Kering dan Perbukitan Kritis. Jakarta, 2–4 Februari 1993. Proyek Pertanian Lahan Kering dan Konservasi Tanah, 141–163.

Hermawan, A. and Prasetyo, T. 1991. Strategi pengembangan rumput unggul di DAS Jratunseluna. Dalam Sistem Usahatani Konservasi di DAS Jratunseluna dan DAS Brantas. Risalah Lokakarya Hasil Penelitian P3HTA/UACP–FSR, Bandungan 25–26 Januari 1991. P3HTA, Badan Litbang Pertanian, 162–172.

Levine, J. 1988. Family level baseline survey results of the UACP. Volume I: SUFS villages of Kabupaten Semarang. Proyek Pertanian Lahan Kering dan Konservasi Tanah Daerah Hulu DAS Jratunseluna-Brantas. Development Alternative Inc.

— 1989. Family level baseline survey results of the UACP DAS Jratunseluna. Volume II: SUFS villages of Kabupaten Boyolali, Grobogan and Blora. P2LK2T DAS Hulu DAS Jratunseluna-Brantas. Development Alternative Inc.

Londhe, S.R., Sureshwaran, S. Abdurachman, A. and Sukmana, S. 1992. Evaluation of investment alternatives in upland agriculture, Central and East Java, Indonesia. A Report to U.S. Agency for International Development.

South Carolina State University, Orangeburg, in cooperation with UACP–FSR, 156 pp.

Lubis, D., Prasetyo, T. Masbulan, E., Hardianto, R. and Hermawan, A. 1991. Dampak usaha ternak dalam usahatani lahan kering daerah aliran sungai bagian hulu serta peluang pengembangannya. Dalam Sistem Usahatani Konservasi di DAS Jratunseluna dan DAS Brantas. Risalah Lokakarya Hasil Penelitian P3HTA/UACP–FSR, Bandungan 25–26 Januari 1991. P3HTA, Badan Litbang Pertanian, 187–205.

Sabrani, M., Levine, J. and Kusnadi, U. 1989. Crop–animal interaction and its implications for design of sustainable farming systems in Indonesia. In: Developments in Procedures for Farming Systems Research. Proceedings of an International Workshop, 13–17 March 1989, Bogor. Agency for Agricultural Research and Development, 221–235.

Saragih, B., Gunardi and Basit, A. 1993. Dampak proyek lahan kering dan konservasi tanah DAS Jratunseluna dan Brantas. Lokakarya Nasional Pembangunan Daerah dalam Rangka Pengelolaan Usahatani Lahan Kering dan Perbukitan Kritis. Jakarta, 2–4 Februari 1993. Proyek Pertanian Lahan Kering dan Konservasi Tanah, 120–140.

Soekardi, M. 1991. Klasifikasi sifat fisik agroekologi di Daerah Aliran Sungai Jratunseluna dan Brantas bagian hulu. Dalam Sistem Usahatani Konservasi di DAS Jratunseluna dan DAS Brantas. Risalah Lokakarya Hasil Penelitian P3HTA/UACP–FSR, Bandungan 25–26 Januari 1991. P3HTA, Badan Litbang Pertanian, 1–15.

Sukmana, S. and Suwardjo, H. 1993. Prospect of vegetative soil conservation measure for sustainable upland agriculture. Indonesia Agricultural Research and Development Journal, 13(1, 2), 1–7.

Suwardjo, H. and Saepudin, A. 1988. Beberapa permasalahan konservasi tanah dan air di DAS Jratunseluna dan DAS Brantas. Risalah Lokakarya Hasil Penelitian Pertanian Lahan Kering dan Konservasi di Daerah Aliran Sungai, Salatiga 14 Maret 1988. P3HTA. Badan Litbang Pertanian, 25–36.

Toha, H.M. and Abdurachman, A. 1991. Penggunaan bahan organik pada pola tanaman lahan kering di tanah vulkanik Eutropept Laboratorium Lapangan Ungaran, Semarang. Risalah Seminar Hasil Penelitian Pertanian Lahan Kering dan Konservasi Tanah di Kabupaten Semarang dan Boyolali. P3HTA. Badan Litbang Pertanian, 115–126.

UACP–FSR. 1992. Laporan Tahunan 1991/1992. Pertanian Lahan Kering dan Konservasi Tanah. P3HTA. Badan Litbang Pertanian.

Potential of Ruminant Production in Pine Plantations and Tree Legume Agroforestry Systems

A.N.F. Perera*, B. Palmer† and C.S. McSweeney§

Abstract

Livestock production under plantation crops is a common practice in developing countries. The botanical composition of the understorey depends on age of the plantation, shade, burning, and method of grazing management. The feed quality of the understorey is a function of the plant species present and their stage of growth. Shade can have both beneficial and detrimental effects on the quality and yield of the undergrowth. Consumption of *Pinus* needles causes digestibility, carcass quality and reproductive problems. Many tropical grasses and legumes can be introduced successfully to *Pinus* plantations and thus improve both stocking rate and animal performance. Higher livestock production can be achieved through agroforestry systems using tree and shrub legumes, both by continuity of feed supply and through higher quality feed. Several species have been proven to be satisfactory and are extensively used. Limitations exist in using some tree and shrub fodders because of the presence of anti-nutrients or secondary compounds. Innovative methods using introduced rumen microorganisms may overcome some of these limitations.

RAPID development in industrial and urban sectors in many developing countries has depleted the availability of natural grazing lands. This has resulted in a need not only to improve productivity from existing grazing land but also to use alternative lands for grazing (for example, under plantation crops such as rubber, oil palm, coconut and pine). The grazing of ruminants under plantation crops is becoming a common practice in many tropical countries.

Plantation crops are established with wide spacings which do not optimally utilise the land area, light and soil moisture available. Weeds will invade and compete with the plantation crop, but give no economic return. In many plantations weed control is costly and noxious species are a problem. Ruminant livestock can be used as 'biological weeders' to eliminate the undergrowth and increase livestock production.

* Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

† CSIRO Division of Tropical Crops and Pastures, Davies Laboratory, Townsville, Queensland, Australia.

§ CSIRO Division of Tropical Animal Production, Long Pocket Laboratory, Brisbane, Queensland, Australia.

Both grasses and broad-leaved weeds (including legumes) are present in the understorey. They may provide a source of edible biomass for livestock feeding, although animal productivity is likely to be low. However, as well as contributing to weed control, livestock grazed on undergrowth will return part of the nutrients as animal excreta. Economically, grazing under *Pinus* is important because it converts non-useable biomass to animal protein (meat and milk). This may generate extra income for the smallholder.

Plantation crops are generally grown on low-fertility marginal lands. To meet the demand for animal protein, these lands could be more productively used under agroforestry systems that included, for example, plantings of shrub legumes and grass.

Botanical Composition of the *Pinus* Understorey

The botanical composition of the understorey is influenced by both aerial and soil environments (Perera 1988), with soil pH and shade the dominant factors. Most of the tropical *Pinus* plantations are diverse and there is some evidence to suggest that the understorey vegetation of *Pinus* plantations is floristically superior to some of the non-forested scrub land and natural grasslands (Bandarathilake 1988). Mature plantations intercept more light (Hawke et al. 1993), resulting in competition between the understorey species. This leads to the elimination of species that are less competitive and intolerant of shade. Improvement can be made by adopting better spacing or changing the orientation of planting. The other major factor influencing species composition is periodic burning of the undergrowth.

In developing countries, many resource-poor livestock farmers depend on state lands to obtain green feed for ruminant livestock. In this respect, the state plantations are a valuable source of fodder for adjacent farmers (Perera 1987; Garrison and Pita 1992). These farmers set fire to the mature and stemmy underbrush during the dry season. The main objective of burning is to yield high quality growth with the subsequent rains. Minerals are also returned as ash.

Another important influence on species composition is grazing management. Many *Pinus* plantations are located on steep terrain where free grazing by cattle is difficult. Therefore, the major grazing management system is cut-and-carry. However, where grazing is practiced, over or undergrazing can severely affect the understorey vegetation (Garrison and Pita 1992).

Effect of *Pinus* on Understorey Yield and Quality

Stocking rate and animal performance are functions of total yield and quality of the understorey. The effects of *Pinus* on understorey may vary, but will ultimately be reflected in animal performance. The presence of tree cover will reduce wind velocity and solar radiation, creating a humid microenvironment and reducing evapotranspiration. The thick *Pinus* needle mulch retains soil moisture. Cool environments associated with satisfactory soil moisture levels result in high vegetative yields and quality. However, excessive shading could lead to low biomass yield and lower quality understorey vegetation. Higher pruning of the *Pinus* crowns will reduce shading and encourage better quality understorey (Hawke et al. 1993).

The morphological changes in response to shade improve leaf production, and enhance animal production by increasing feed intake and digestibility. Low intensity of light reduces the dry matter content. At 27% available light, the dry matter is reduced to 16–18% (Wong et al. 1985a,b). There are reports that shade consistently reduces the non-structural carbohydrates, resulting in low digestibility and palatability. This has been related to high cell-wall lignin and silica (Wilson 1982).

Livestock Performance under *Pinus*

Many studies have suggested that substantial quantities of high quality dry matter are produced under *Pinus*, but that, because of seasonal fluctuation in feed quality, the performance of livestock is not uniform. At the end of the rainy season the understorey of tropical *Pinus* plantations stops growing and begins to mature. Such feed becomes less palatable and digestible. These leaner periods demand supplementation to maintain livestock performance. What species of livestock are best introduced into the plantation depends on the nature of the understorey and the types of plant species present. When grasses form a major part of the understorey, cattle or sheep are preferred, but for brushwood understorey goats are ideal. In a well grown understorey with broad species diversity, the nitrogen content of the biomass is sufficient to maintain rumen ammonia nitrogen levels adequate for optimum activity of rumen microbes (Ulyatt et al. 1980).

Among the benefits of grazing under *Pinus* are:

- indirect effects on animals through pasture quality;
- reduced livestock maintenance requirements due to cooler microclimate;
- improved yields of milk, meat and wool as a result of low maintenance requirement;
- decreased lamb mortality and better protection of sheared sheep (Penaloza and Harve 1984).

When the understorey feed source is insufficient, or when overstocking occurs, the grazing livestock tend to eat fallen pine needles. Decaying pine needles are low in digestibility (Hawke et al. 1984). Inclusion of up to 30% pine needles in the diet has resulted in reduction in rumen bacteria and protozoans. Pine needles severely affect the nitrogen intake and digestibility of the grass.

Pine needles contain shikimic acid, several monomeric phenolic compounds, and flavonoids and tannins (Adams et al. 1992). These compounds can influence the quality of livestock products. Percival et al. (1988) found that when pine needles were fed to sheep, a change in muscle colour and pH occurred, but no changes were observed in flavour, aroma, tenderness, juiciness and texture. The presence of 'abortifacient' compounds has been reported (James et al. 1989). These compounds are more concentrated in *Pinus* bark and the growing tips of branches than in needles (Panter et al. 1992). The effect of these abortifacient substances is mainly on pregnant cows. Premature parturition is more likely when the needles are consumed after 8 months of pregnancy, or over a period of more than three days, or in excessive amounts (2.2–2.7 kg/day). The effect of pine needles on the pregnancy of buffaloes is similar to that in cattle (Panter et al. 1992). Pregnant sheep and goats are not affected (Short et al. 1992).

Many studies have shown that animals grazed under *Pinus* are less productive than those on open pasture or in other agroforestry systems.

Introduction of Improved Pastures under *Pinus*

Because of the fluctuation in yield and quality, and the resulting poor and variable animal performance, many attempts have been made to introduce improved pasture grasses and legumes into *Pinus* plantations. To succeed, introduced species should have the following characteristics: shade tolerance, adaptation to high soil acidity and low fertility, high rate of regeneration, tolerance to heavy grazing and fire damage, and ability to withstand high needle litter and soil moisture stress.

Improved pastures require management and cultural practices to maintain high productivity (Pearson and Baldwin 1993). Premalal and Perera (1993) reported that establishment of *Paspalum plicatulum* and *Chloris gayana* in an 8-year-old *Pinus* plantation gave annual dry matter yields of 9500 and 10000 kg/ha, respectively. In association with *Centrosema pubescens* the dry matter yields were 11000 and 12000 kg/ha. Briscoe (1983) maintained buffalo and cattle under *Pinus* on *Panicum maximum* and *Brachiaria humidicola*.

Soil acidity is one of the limiting factors in establishing forage legumes under *Pinus*. Low pH, associated with high shade levels, results in low nitrogen fixation by the pasture legumes, leading to low dry matter production and quality. *Pueraria phaseoloides* and *Calopogonium mucunoides* perform better under low pH than do many other tropical pasture legumes (Samarasinghe et al. 1992). Due to the many limitations existing under *Pinus*, little progress has been made in introducing improved pastures.

Shrub and Tree Legumes as a Source of Feed for Ruminants

Research in agroforestry is commonly concerned with the optimisation of spatial and temporal combinations of trees–shrubs and herbaceous species, and their management to achieve the goals of productivity and sustainability. In choosing the combination and spatial association, factors such as competitiveness, shade tolerance and animal tolerance of the plants have to be considered. Unlike plantation systems, both components are utilised as animal feed. The tree or shrub legumes are included to add a highly nutritious protein supplement to the lower quality grass component. The inclusion of the tree or shrub legume can also act as a buffer against the feed gaps that occur from the seasonal fluctuations in the productivity of the herbaceous forage.

Many tree and shrub legumes are grown for animal feed, the most common species coming from the genera *Acacia, Albizia, Calliandra, Desmanthus, Desmodium, Gliricidia, Leucaena, Prosopis* and *Sesbania* (Brewbaker 1986; Perera 1992, 1994). *Leucaena leucocephala* (leucaena) is by far the most widely cultivated tree legume. However, due to attack by the leucaena psyllid (*Heteropsylla cubana*) many tropical leucaena plantations have recently been threatened. In Asia and Africa, where livestock are raised in small numbers by smallholder farmers, tree legumes are commonly planted as fodder banks in hedgerows or on unused lands. They are also grown on rice paddy bunds and on contours to minimise erosion. In extensive grazing systems, tree legumes are planted in association with improved grasses. Live weight gains of up to 1.0 kg/head/day can be achieved at stocking rates up to 4 animals/ha. In these systems leucaena is sown in rows 4–12 m apart and grasses are sown between the leucaena rows. The improved grasses grown in these systems include *Panicum maximum, Brachiaria decumbens, Digitaria eriantha, Chloris gayana* and *Setaria sphacelata*.

Once established, the height and deep-rooting habit of most tree legumes buffer them from serious competition from the adjacent herbaceous layer. However, as seedlings they are usually slow growing and require protection from competing grasses and weeds in their establishment phase (Maasdorp and Gutteridge 1986). For example, the management of the tree legume–grass system may be easier where leucaena is established in a block with a row spacing narrow enough to allow cultivation at establishment. Canopy closure minimises weed growth once the leucaena is fully established. The grass is grown on an adjacent area. This system is amenable to grazing and to cut-and-carry. Animal productivity using separate areas of nitrogen-fertilised *Brachiaria decumbens* (brachiaria) and *Calliandra calothyrsus* (calliandra) is at present being evaluated in northern Australia. Preliminary data show an improvement of 30% by allowing cattle to graze calliandra and nitrogen-fertilised *Brachiaria decumbens* rather than fertilised brachiaria alone. Over a period of a year, no damage has been caused to calliandra by the grazing cattle.

Nutrient Value of Tree Legumes

A critical factor in the determination of intake requirement of forage is the physiological state of the animal. The animal's condition and state of health affect the energy requirement of the tissues and thus the feed intake. The ingested feed provides the substrate, but nutrient yield is largely the product of microbial activity in the rumen. Nutrient yield is the net effect of all the processes of fermentation, microbial growth and the flow of microbial and dietary components to the small intestine. The pattern of nutrient yield must match the nutrient requirement of the animal. Tropical tree–shrub legumes, due to their lower seasonal variation in quality (Bamualim 1981), have an important role in providing a stimulus for the intake of dry season grasses. The crude protein content of tree legumes is usually high (12–30%) compared with mature tropical grasses (3–10%) and tree legumes are considered a high quality feed for supplementing the base diet.

Limitations in Using Tree and Shrub Legumes as a Feed

Tree and shrub legumes often contain anti-nutrients or plant secondary compounds which can severely restrict their feed value. The term secondary compound is used to describe a group of chemical constituents not directly involved in the biochemical processes of growth and reproduction in plants. These secondary compounds are thought to have a defensive role (Coley et al. 1985, Perera 1994), protecting the plant against insect feeding or by restricting grazing by herbivores (Swain 1979). Their elimination may not be compatible with high production. Moderate quantities of these compounds can be tolerated, especially where the offending plant is not used as the sole diet.

As summarised by Barry and Blaney (1987), secondary compounds can be toxic to animals, or cause a reduction in their productivity by reducing feed intake. The effects of these secondary compounds on ruminants are less severe than on monogastrics. The ruminants are able to break down the ingested secondary compounds in the rumen by microbial activity. When leucaena is fed to ruminants, the secondary compound mimosine is readily detoxified by the rumen microbes, if the appropriate organism is present (Jones 1994).

Most compounds in natural forages, including anti-nutritive factors, are metabolised by rumen microorganisms. However, our knowledge of the ecology and physiology of the gastrointestinal microorganisms that metabolise these substances is limited, especially for anti-nutritive factors associated with shrub legumes. A better understanding of these processes might allow us to manipulate ruminal populations and the metabolism of anti-nutritive factors. Apart from mimosine, phenolic compounds are the major group of anti-nutritive factors in shrub legumes. An understanding of the microbial ecology and metabolism of phenolics and related compounds in leguminous plants is a necessary starting point to permit optimal utilisation of tannin-containing shrub legumes. This information will provide the basis for isolating microorganisms from herbivores that are adapted to degrade tannins or digest high tannin forages. Colonising the rumen of domesticated ruminants with such organisms could lead to a marked improvement in animal productivity.

References

Adams, D.C., Pfister, J.A., Short, R.E., Cates, R.G., Knapp, B.W. and Wiedmeier, R.D. 1992. Pine needle effect on in vivo and in vitro digestibility of crested wheat grass. Journal of Rangeland Management, 45, 249–253.

Bamualim, A. 1981. Nutritive value of some tropical browse species in the wet and dry season. M.Sc. Thesis, Department of Veterinary Science, James Cook University of North Queensland, Townsville, Australia.

Bandarathilaka, H.M. 1988. Development of pine plantations in Sri Lanka. In: Gunasena, H.P.M., Gunathilaka, S. and Perera, A.H., ed., Reforestation with *Pinus* in Sri Lanka. University of Peradeniya, Sri Lanka, 10 p.

Barry, T.N. and Blaney, B.R. 1987. Secondary compounds of forages. In: Hacker, J.B. and Ternouth, J.H., ed., The nutrition of herbivores. Sydney, Academic Press, 91 p.

Brewbaker, J.L. 1986. Leguminous trees and shrubs for Southeast Asia and the South Pacific. In: Blair, G.J., Ivory, D.A. and Evans, T.R., ed., Forages in Southeast Asian and South Pacific agriculture. Canberra, ACIAR Proceedings No. 12, 43 p.

Briscoe, C.B. 1983. Integrated forestry–agriculture–livestock land use at Jari Florestal e Agropecuaria. In: Huxley, P.A., ed., Plant research and agroforestry. Nairobi, Kenya, ICRAF, 63 p.

Coley, P.D., Bryant, J.P. and Chapin, F.S. 1985. Resource availability and plant antiherbivore defence. Science, 230, 895–899.

Garrison, M. and Pita, M. 1992. An evaluation of silvopastoral systems in pine plantations in the central highlands of Ecuador. Agroforestry, 18, 1–16.

Hawke, M.F., Jagush, K.T. and Newth, R.P. 1984. Feeding sheep decaying pine needles. Agroforestry Systems, 14, 23–24.

Hawke, M.F., Rattray, P.V. and Percival, N.S. 1993. Liveweight changes of sheep grazing a range of herbage allowances under *Pinus radiata* agro-forestry regimes. Agroforestry Systems, 23, 11–21.

James, L.F., Short, R.E., Panter, K.E., Moluneux, R.J., Stuart, L.D. and Bellows, R.A. 1989. Pine needle abortion in cattle: a review and a report of 1973–1984 research. Cornell Veterinarian, 79(1), 39–52.

Jones R.J. 1994. Management of anti nutritive factors — with special reference to *Leucaena*. In: Gutteridge, R.C. and Shelton, H.M. ed., Forage tree legumes in tropical agriculture. Wallingford, U.K., CAB International, 216 p.

Maasdorp, B.V. and Gutteridge, R.C. 1986. Effect of fertilizer and weed control on the emergence and early growth of five leguminous fodder shrubs. Tropical Grasslands, 20, 3–10.

Panter, K.E., James, L.F. and Molyneuse, R.J. 1992. Ponderosa pine needles induce parturition in cattle. Proceedings of the American Society for Animal Science, 70, 1604–1608.

Pearson, H.A. and Baldwin, V.C. 1993. Agroforestry: southern pines and subterranean clover cultural treatments. Agroforestry Systems, 22, 49–58.

Peneloza, R. and Harve, M. 1984. Pastoreo permanente de ovinosen plantacions forestales en la Decima Region. Proxima Decada, Chile, 24, 16–21.

Percival, N.S., Hawke, M.F., Kirton, A.H. and Hagyard, C. 1988. Meat flavour of Romney lambs grazed under *Pinus radiata*. Proceedings of the New Zealand Society for Animal Production, 48, 13–17.

Perera, A.H. 1987. An evaluation of regeneration potential in *Pinus* plantations of the central region of Sri Lanka. Ph.D. Dissertation, Pennsylvania State University, USA.

— 1988. Ecological issues on pines in Sri Lanka. In: Gunasena, H.P.M., Gunathilaka,S. and Perera, A.H., ed., Reforestation with *Pinus* in Sri Lanka. University of Peradeniya, Sri Lanka, 56 p.

Perera, A.N.F. 1992. *Gliricidia* as a fodder in livestock production — Sri Lanka experience. In: Gunasena, H.P.M. ed., Multipurpose tree species in Sri Lanka. Research and Development, Sri Lanka, 72–84.

— 1994. Growth and feeding value of four leguminous shrub species grown as hedgerows in mid country of Sri Lanka. Consultants Report, GTZ Upper Mahaweli Watershed Management Project, Sri Lanka.

Premalal, G.E.C. and Perera, A. 1993. Forest pasture systems for different climatic zones in Sri Lanka. Annual Research Review of Veterinary Research Institute, Sri Lanka, 12 p.

Samarasinghe, S.J., Gunathilaka, N., Gunathilaka, S. and Ashton, P.M.S. 1992. Ground covers and shade trees performance of mixed species plantation trials at Hantane grasslands. In: Proceedings of the Sri Lanka Association for the Advancement of Science (Abstract).

Short, R.E., James, L.F., Panter, K.E., Staigmiller, R.B., Bellows, R.A., Malcolm, J. and Ford, S.P. 1992. Effect of feeding Ponderosa pine needles during pregnancy; comparative studies with bison, cattle, goats and sheep. Journal of Animal Sciences, 70, 3498–3504.

Swain, T. 1979. Tannin and lignins. In: Rozenthal, G.A. and Janzen, D.H. ed., Herbivores and their interaction with secondary metabolites. New York, Academic Press.

Ulyatt, M.J., Fennessy, P.F., Rattray, P.V. and Jagusch, K.T. 1980. The nutritive value of supplements. New Zealand Society for Animal Production Occasional Publications, 7, 157–184.

Wilson, J.R. 1982. Environmental and nutritional factors affecting herbage quality. In: Hacker, J.B., ed., Nutritional limits to animal production from pasture. Farnham Royal, U.K., CAB International, 111–131.

Wong, C.C., Rahim, H. and Sharudin, M.A. 1985a. Shade tolerance potential of some tropical forages for integration with plantations. 1. Legumes. MARDI Research Bulletin, 13, 249–269.

Wong, C.C., Sharudin, M.A. and Rahim, H. 1985b. Shade tolerance potential of some tropical forages for integration with plantations. 1. Grasses. MARDI Research Bulletin, 13, 225–247.

Plantation-based Agroforestry Systems for Livestock Production on Tin Tailings in Peninsular Malaysia

A.N.A. Ghani*, N.M.N.A. Majid*, C.P.M. Chellapan* and M.N. Shamsuddin†

Abstract

Tin tailings have a great potential to be developed for livestock production through agroforestry practices if proper land management is adopted. This paper highlights two agroforestry systems for livestock production, namely agrosilvopastoral and silvopastoral, which have been implemented in the state of Selangor, Malalysia. The main emphasis was to evaluate the economics of these agroforestry systems. Data on benefits and costs were collected from two agencies involved in implementing these agroforestry systems. Secondary data were also collected from relevant agencies. Data were analysed to evaluate the economic viability of these agroforestry systems using three criteria, namely net present value (NPV), internal rate of return (IRR) and benefit–cost ratio (BCR). The results indicate that both agroforestry systems are economically viable. The net present value (NPV) is positive, internal rate of return (IRR) is greater than the opportunity cost, and the benefit–cost ratio (BCR) is greater than one. Results from sensitivity analysis indicate that the systems are still viable even with reduction in benefits and increase in costs. Thus, large-scale agroforestry systems on tin tailings for livestock production can be implemented to obtain maximum return from agroforestry projects. Further research on the role of its components, and its relationship with the environment, is required to enable development of environmentally sound systems over the long run.

TIN tailings are wastelands made up of washed waste products of alluvial mining (Nik Muhamad 1990). There are two main components in tin tailings: sand tailing and slime tailing. Sand tailing is characterised by coarse texture and lack of aggregation; the slime tailing has compact structure due to the presence of very fine silt and clay.

The area under tin tailings is estimated to be approximately 113 700 ha or about 0.86 % of the total land area (Table 1). Tin tailings are largely found in two states: Perak (63%) and Selangor/Federal Territory of Kuala Lumpur (25%). This is due to the large tin deposits found in these two states.

The productive use of tin tailings is important to provide maximum economic return to land owners. Among the productive uses of tin tailings are agriculture projects, housing estates, industrial-based activities, and sports-based projects. However, tin tailings have been productively used only for nonagricultural purposes. Planting with agricultural crops is possible, but on a small scale. Problems arise because of poor soil structure, low nutrient and organic matter content, low cation exchange capacity and low water-holding capacity (Maene et al. 1977; Lim et al. 1981; Shamsuddin et al. 1986).

Efforts aimed at increasing the productive use of tin tailings for a specific purpose have been made and have achieved some success. For instance, Kho et al. (1979) highlight several farming systems available on tin tailings. These include intensive vegetable cultivation, planting of fruit trees (pomelo, papaya, star fruit, and guava), planting of field crops (tapioca, groundnuts, and sugarcane) and livestock production (pig, poultry, and cattle). In fact, increasing productivity of tin tailings through agroforestry practice is not new. Birkenshaw (1931) first investigated the possibility of planting tin tailings with crops. The prospects of reclaiming tin tailings were further studied by Mitchell (1957). Other physiological aspects of agricultural

* Faculty of Forestry, Universiti Pertanian Malaysia, Malaysia 43400.

† Faculty of Economics, Universiti Pertanian Malaysia, Malaysia 43400.

Table 1. Land use of tin tailings by states, Peninsular Malaysia, 1990 (Chan 1990).

State	Total tin tailings area (ha)	Agricultural use (ha)	Nonagricultural use
Perlis	n.a.	n.a.	n.a.
Kedah	2500	10	20
Penang	10	n.a.	n.a.
Perak	71850	3890	2300
Selangor/Federal Territory Kuala Lumpur	28250	830	3920
Negeri Sembilan	2090	•	•
Malacca	380	•	•
Johore	5660	•	•
Pahang	2910	n.a.	n.a.
Terengganu	40	n.a.	n.a.
Kelantan	n.a.	n.a.	n.a.
Total	113700	47430	6240

n.a. = not available

• = neglible

practices on tin tailings have been conducted by Reid (1956). Its edaphalogy and ecology has also been studied by Palaniappan (1972, 1974).

More recently, Lim et al. (1990) pointed out that tin tailings are suitable for agroforestry practices on a large scale. This can be done through the integration of timber, agricultural crops and animals. This paper highlights two agroforestry systems — agrosilvopastoral and silvipastoral, which can be implemented on tin tailings for livestock production. The main emphasis of the paper is to evaluate the economic viability of each system based on outputs produced during the duration of the project cycle. It should be pointed out that only the tangible benefits are considered. Intangible benefits such as protection of nutrient loss also play an important role in maintaining sustainability and productivity of tin tailings. These benefits are not included due to complexities in valuing them.

General Approach of the Study

The general approach adopted in this study was to employ with and without project evaluation as suggested by Gittinger (1982). Incremental net benefits were calculated using the difference between the net benefits arising from outputs of agroforestry systems and the net benefits without the project, that is from sales of sand to construction companies.

The study areas are located in two tin tailings in Selangor, Malaysia. The first site (10 ha) was established in 1986 and is located to the northwest of Kuala Lumpur (3°20', 101°25'). In this site, fast growing timber species (*Acacia mangium*) in combination with agricultural crops (oil palm, mango, durian, and coconut) were planted in a zonal arrangement. Sheep were introduced into the area for livestock production. As such, this agroforestry system is known as agrosilvopastoral.

The second site (8 ha) is located to the southeast of Kuala Lumpur (2°5', 101°50'), and is planted with fast growing timber species (*Acacia mangium*) and pasture (*Setaria anceps var. splendia*). This system is silvopastoral; however, livestock have not yet been introduced into this area.

The two sites differ in terms of their soil composition. The site for the agrosilvopastoral system is a combination of sand and slime tailings, whereas the silvopastoral system is characterised by sand tailings. The mean annual rainfall in both sites differs: 2500 mm and 2975 mm in the agrosilvopastporal and silvopastoral areas, respectively.

Detailed characteristics and components of the two systems are given in Table 2.

Identification of Benefits and Costs

Benefits from the agrosilvopastoral system were the sales of timber species, agricultural crops, and mutton. For the silvopastoral system, the benefits were the sales of timber and pasture. Salvage value was also included at the end of the project duration.

Table 2. Characteristics of the research sites and system components.

Area characteristic/system component	Agroforestry system	
	Agrosilvopastoral	Silvopastoral
Area (ha)	10	8
Year established	1986	1988
Mean annual rainfall (mm)	2500	2975
Mean daily temperature (°C)	30	26
Soil characteristics	sand and slime	sand tailings
Project cycle (years)	25	25
Timber species	*Acacia mangium* (2 ha)	*Acacia mangium* (5.6 ha)
Plantation crop	oil palm (5.5 ha), durian (0.2 ha)	none
Agriculture crop	mango (0.3 ha)	none
Livestock	sheep, 5 ha	none
Pasture	none	*Setaria anceps var. splendia* (2.4 ha)
Cropping arrangement	zonal	zonal

All costs were categorised as establishment, material, labour, capital and maintenance costs. Detailed categories of costs and benefits for each agroforestry system are provided in Tables 3 and 4.

Data Sources

Data were obtained from primary and secondary sources. Data on costs were collected from published reports by the Malaysian Agriculture Research and Development Authority (MARDI), and companies involved in the project. Establishment costs were categorised into site preparation, planting, fertilising, transportation, material, fencing, mulching, mounding, harvesting, pruning, drainage, and weeding. The prices of the products (timber, oil palm, fruits, livestock, and sand) were gathered from reports published by the Forestry Department, Ministry of Primary Industry, Federal Agriculture Marketing Authority (FAMA), and the Department of Mines.

All costs and benefits involved in the projects were valued on the basis of opportunity cost. In this study, the opportunity cost or shadow price for each category was calculated using the conversion factor approach. The values for the conversion factors for all items listed under costs and benefits were obtained from Veitch (1986).

An economic cash flow table was prepared for each agroforestry system in order to compare with and without project benefits and costs in each year (Tables 5 and 6). Then, the net incremental costs and benefits were determined. The duration of the project in both sites is 25 years.

Measures of Project Worth

To evaluate the economic viability of each project, three methods of investment criteria were used.

Net present value (NPV)

NPV is the summed discounted net value of the cash flow produced by the project. The formula is given as:

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+i)^t}$$

where B_t = benefits in each year t
C_t = costs in each year t
n = number of years to complete the project
t = year
i = discount rate

The criterion for choice is to invest in any agroforestry project in which NPV is positive.

Internal rate of return (IRR)

IRR is the rate of discount that reduces the cash flow of an agroforestry project to a zero net present value. The formula is given as:

$$IRR = \sum_{t-0}^{n} \frac{(B_t - C_t)}{(1+i)^t} = 0$$

Table 3. Benefits and costs: agrosilvopastoral system.

Revenue and Costs: Betang Berjuntai (25 years)	Year									
	1	2	3	4	5	6	7	8	9	10
1) Oil palm										
A) Yield (tonnes/ha)	0.00	0.00	0.00	7.90	18.94	19.49	18.56	22.56	21.62	19.83
Unit price FOB Palm Oil (RM/tonne)				701.00	836.50	836.50	948.80	948.80	948.80	948.80
Total hectarage (ha)	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
Total Sales Revenue (RM)	0.00	0.00	0.00	30458.45	64134.46	89668.62	96853.50	117727.10	112821.81	103480.87
Revenue (RM/ha)	0.00	0.00	0.00	5593.28	11777.42	16466.42	17785.83	21618.98	20718.19	19002.85
Total Sales Revenue at AP(RM)	0.00	0.00	0.00	30763.03	64775.80	90565.30	97822.04	118904.38	113950.03	104515.68
B) Costs (RM)										
Investment	7540.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weeding	2020.00	2282.83	1547.24	546.41	636.30	546.41	537.32	525.20	323.20	242.40
Spraying	202.00	215.82	524.19	215.13	344.41	215.13	0.00	0.00	0.00	0.00
Manuring/mulching	3575.40	1900.01	766.59	627.83	627.83	627.83	627.83	566.61	232.30	333.30
Supplying	0.00	32.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harvesting/others	3838.00	65258	1425.20	773.04	1110.38	1188.15	1188.15	1066.56	1066.56	1161.50
Total Cost at AP(RM)	17176.31	4496.52	4264.22	2162.41	2718.92	2577.52	2353.30	2158.37	1622.06	1737.20
Cost (RM/ha)	3122.97	817.55	775.31	393.17	494.35	468.64	427.87	392.43	294.92	315.85
Net Revenue (RM/ha)	-3122.57	-817.55	-775.31	-393.17	-494.35	-468.64	-427.87	-392.43	-294.92	-315.85
Net Revenue at AP (RM)	-17176.312	-4496.52	-4264.22	28600.6245	62056.87	87987.78	95468.73	116746.0	112327.9	102778.4
Consumer Price Index (%)	0.60	0.80	2.50	2.80	3.10	4.40	4.70	3.80	3.50	3.50
CPI (1990 = 1.00)	0.19	0.26	0.81	0.90	1.00	1.42	1.52	1.22	1.13	1.13
Net Revenue (RM/ha) at constant price relative to 1990	-16436.66	-3144.42	-957.18	-436.85	-494.35	-330.03	-281.50	-321.66	-260.99	-279.52
Net Revenue (RM) at constant price relative to 1990	-90401.644	-17294.307	-5264.4691	31778.4716	62056.87	61963.22	62808.38	95693.44	99405.27	90954.40
2) Timber										
A) Yield (cu.m./ha)	0	0	0	0	0	0	0	183.4	0	0
Unit Price FOB Timber (RM/cu.m..)						447.91	479.56	609.04	609.04	609.04
Total hectarage (ha)	2	2	2	2	2	2	2	2	2	2
Total sales revenue at AP (RM)	0	0	0	0	0	0	0	234564.10	0	0
Revenue (RM/ha)	0	0	0	0	0	0	0	117282.0	0	0
B) Costs (RM)										
Investment	2850.75	0	0	0	0	0	0	0	0	0
Weeding	2184.00	1174.87	433.65	0	0	0	0	0	0	0
Spraying	2415.00	58.03	52.50	0	0	0	0	0	0	0
Manuring/mulching	526.05	20.37	0	0	210.00	105.00	105.00	52.50	0	0
Pruning	0	0	273.00	0	0	0	273.00	0	0	0
Harvesting/others	1277.85	116.98	107.10	221.55	326.55	610.05	577.50	577.50	577.50	840.00
Total Cost at AP (RM)	9253.85	1370.25	868.25	221.55	536.55	715.05	955.50	630.00	577.50	840.00
Total Cost (RM/ha)	4626.83	685.13	433.13	110.78	268.28	357.53	477.75	315.00	288.75	420.00
Net Revenue (RM/ha)	-4858.17	-685.13	-433.13	-110.78	-268.28	-357.53	-477.75	116967.05	-288.75	-420.00
Net Revenue at AP (RM)	-9253.65	-1370.25	-866.25	-221.55	-536.55	-715.05	-955.5	233934.0	-577.5	-840
Consumer Price Index (%)	0.6	0.8	2.5	2.8	3.1	4.4	4.7	3.8	3.5	3.5
CPI (1990 = 1.00)	0.19	0.26	0.81	0.90	1.00	1.42	1.52	1.22	1.13	1.13
Net Revenue (RM/ha) at constant price relative to 1990	-25569.30	-2635.10	-534.72	-123.08	-268.28	-251.78	-314.31	95874.63	-255.53	-371.68
Net Revenue (RM) at constant price relative to 1990	-48703.421	-5270.1923	-1069.4444	-246.1665	-536.55	-503.556	-6283618	-191749.2	-511.061	-743.362
3) Sheep										
A)Yield (kg)	0.00	0.00	100.00	150.00	150.00	150.00	180.00	200.00	250.00	350.00
Unit Price meat (RM/kg)			5.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00
Total Sales Revenue aat AP (RM)	0.00	0.00	460.00	690.00	690.00	690.00	993.60	1104.00	1380.00	1932.00
B) Costs (RM)										
Investment	2497.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	920.00	0.00
Feed and treatment	441.60	441.60	441.60	220.80	220.80	220.80	220.80	220.80	220.80	220.80
Pasture: weeding	99.39	144.44	99.36	99.36	99.36	92.00	46.00	46.00	46.00	46.00
Spraying	0.00	0.00	184.00	184.00	184.00	0.00	0.00	0.00	0.00	0.00
Manuring/mulching	281.61	1516.16	1626.56	706.56	706.56	460.00	460.00	460.00	368.00	368.00
Attendant	2300.00	583.28	921.84	921.84	92.00	0.00	0.00	0.00	0.00	0.00
Harvesting/others	3330.28	0.00	633.88	486.68	0.00	207.92	207.92	207.92	207.92	207.92
Total Cost at AP (RM)	8950.68	2685.48	3907.24	2619.24	1302.72	980.72	934.72	934.72	1762.72	842.72

Table 3. (continued)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
20.12	20.87	21.62	21.60	20.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80	948.80
5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
104994.21	108908.01	112821.81	112717.44	105933.52	93931.20	93931.20	93931.20	93931.20	93931.20	93931.20	93931.20	93931.20	93931.20	93931.20
19280.75	19999.47	20718.19	20699.02	19453.25	17249.18	17249.18	17249.18	17249.18	17249.18	17249.18	17249.18	17249.18	17249.18	17249.18
105044.15	109997.09	113980.03	113844.61	106992.86	94870.51	94870.51	94870.51	94870.51	94870.51	94870.51	94870.51	94870.51	94870.51	94870.51
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40	242.40
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30	333.30
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50	1161.50
1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20	1737.20
315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85	315.85
-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85	-315.85
104306.9	108259.8	112212.8	112107.4	105255.6	93133.31	93133.31	93133.31	93133.31	93133.31	93133.31	93133.31	93133.31	93133.31	93133.31
3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52	-279.52
92307.03	95805.21	99303.38	99210.10	93146.59	82418.86	82418.86	82418.86	82418.86	82418.86	82418.86	82418.86	82418.86	82418.86	82418.86
0	0	0	0	81.2	0	0	0	16.5	0	31.2	0	52.4	0	0
609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
0	0	0	0	103853.50	0	0	0	21103.24	0	39904.30	0	67018.76	0	0
0	0	0	0	51926.75	0	0	0	10551.61	0	19952.15	0	33509.38	0	0
0	0	0	0	0	1050.00	0	0	0	0	0	0	0	0	0
0	0	0	0	0	525.00	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1050.00	0	0	0	0	0	0	0	0	0
0	0	525.00	0	0	105.00	210.00	0	0	0	0	0	525.00	210.00	315.00
0	0	273.00	420.00	0	0	273.00	0	0	0	0	0	273.00	0	0
840.00	420.00	420.00	420.00	420.00	577.50	210.00	420.00	420.00	840.00	840.00	420.00	420.00	420.00	420.00
882.00	420.00	1218.00	840.00	420.00	3472.88	693.00	420.00	420.00	840.00	882.00	420.00	1218.00	830.00	735.00
441.00	210.00	609.00	420.00	210.00	1736.44	346.50	210.00	210.00	420.00	441.00	210.00	609.00	315.00	367.50
-441.00	-210.00	-609.00	-420.00	51716.75	-1736.44	-346.50	-210.00	10341.62	-420.00	19511.15	-210.00	32900.38	-315.00	-367.50
-882	-420	-1218	-840	103433.5	-3472.87	-693	-420	20683.23	-840	39022.30	-420	65800.76	-630	-735
3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
-390.27	-185.84	-538.94	-371.68	45767.04	-1536.67	-306.64	-185.84	9151.87	-371.68	17266.50	-185.84	29115.38	-278.76	-325.22
-780.530	-371.681	-1077.87	-743.362	91534.08	-3073.34	-613.274	-371.681	18303.74	-741.362	34533.00	-371.681	58230.76	-557.522	-650.442
350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00	350.00
6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00	1932.00
0.00	920.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80	220.80
46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00	46.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00	368.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92	207.92
842.72	1762.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72	842.72

Table 3. (continued)

Revenue and Costs: Betang Berjuntai (25 years)	Year									
	1	2	3	4	5	6	7	8	9	10
Net revenue at AP (RM)	-8950.68	-2685.48	-3447.24	-1929.24	-612.72	-290.72	58.88	169.28	-382.72	1089.28
Consumer Price Index (%)	0.6	0.8	2.5	2.8	3.1	4.4	4.7	3.8	3.5	3.5
CPI (1990 = 1.00)	0.19	0.26	0.81	0.90	1.00	1.42	1.52	1.22	1.13	1.13
Net Revenue (RM) at constant price relative to 1990	-47108.84	-10328.77	-4255..85	-2143.60	-612.72	-204.73	38.74	138.75	-338.69	963.95
4) Mangoes										
A) Yield (kg/ha)	0.00	0.00	0.00	2115.00	4371.00	4371.00	7332.00	7332.00	7990.00	7990.00
Unit Price FOB (RM/kg)				1.70	1.75	1.75	1.80	1.90	1.90	1.90
Total hectarage (ha)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total Sales Revenue at AP (RM)	0.00	0.00	0.00	1186.52	2524.25	2524.25	4355.21	4597.16	5009.73	5009.73
Revenue (RM/ha)	0.00	0.00	0.00	3955.05	8414.18	8414.18	14517.36	15323.88	16699.10	16699.10
B) Costs (RM)										
Investment	447.98	0.00	80.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weeding	276.83	116.60	326.70	.26.70	326.70	326.70	326.70	326.70	326.70	326.70
Spraying	0.00	190.30	155.10	155.10	155.10	155.10	155.10	155.10	155.10	155.10
Manuring/mulching	77.25	77.00	189.20	189.20	189.20	189.20	189.20	189.20	189.20	189.20
Wrapping	364.57	132.00	562.10	562.10	562.10	232.10	232.10	232.10	232.10	232.10
Harvesting/others	1094.35	221.10	2007.60	774.90	1026.90	199.90	199.90	199.90	199.90	199.90
Total cost at AP (RM)	2442.28	810.70	3653.10	2208.80	2486.00	1213.30	1213.30	1213.30	1213.30	1213.30
Cost (RM/ha)	8140.92	2702.33	12177.00	7362.67	8286.67	4044.33	4044.33	4044.33	4044.33	4044.33
Net revenue (RM/ha)	-8955.01	-2972.57	-13394.70	-3748.38	140.26	4806.83	11520.33	12407.50	13920.24	13920.24
Net Revenue at AP (RM)	-2442.28	-810.70	-3653.10	-1022.29	38.25	1310.95	3141.91	3383.86	3796.43	3796.43
Consumer Price Index (%)	0.6	0.8	2.5	2.8	3.1	4.4	4.7	3.8	3.5	3.5
CPI (1990 = 1.00)	0.19	0.26	0.81	0.90	1.00	1.42	1.52	1.22	1.13	1.13
Net Revenue (RM/ha) at constant price relative to 1990	-47131.62	-11432.95	-16536.67	-4164.86	140.26	3385.09	7579.16	10170.08	12318.80	12318.80
Net Revenue (RM) at constant price relative to 1990	-12854.08	-3118.06	-4510.00	-1135.87	38.25	923.21	2067.04	2773.66	3359.67	3359.67
5)Durians										
A) Yield (tonnes/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1316.00	2162.00	3008.00
Unit Price (RM/ha)								1.66	1.66	1.66
Total hectarage (ha)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Total Sales Revenue at AP (RM)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	415.07	681.89	948.72
Revenue (RM/ha)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2075.33	3409.47	4743.62
B) Costs (RM)										
Investment	264.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weeding	310.99	105.45	248.90	57.00	105.45	105.45	285.95	105.45	105.45	105.45
Spraying	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50
Manuring/mulching	63.32	63.32	160.82	30.72	58.27	63.32	158.32	63.32	63.32	63.32
Harvesting/others	482.19	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73
Total Cost at AP (RM)	1152.83	322.05	534.85	226.95	301.15	322.05	1302.45	322.05	322.05	322.05
Cost (RM/ha)	5764.13	1610.25	2674.25	1144.75	1505.75	1610.25	6515.25	1610.25	1610.25	1610.25
Net Revenue at AP (RM)	-1152.83	-322.05	-534.85	-228.95	-301.15	-322.05	-1302.45	93.02	359.84	526.67
Net Revenue (RM) at constant price relative to 1990	-6067.50	-1238.65	-660.31	-254.39	-301.15	-226.80	-856.88	76.24	318.45	554.58

Table 3. (continued)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1089.28	1089.28	1089.28	1089.28	1089.28	1089.28	169.28	1089.28	1089.28	1089.28	1089.28	1089.28	1089.28	1089.28	1089.28
3.5	3.5	3.5	3.5	3.53.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96	963.96
7990.00	7990.00	7990.00	7990.00	7990.00	0.00	0.00	0.00	2115.00	4371.00	4371.00	7332.00	7332.00	7990.00	7990.00
1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
5009.73	5009.73	5009.73	5009.73	5009.73	0.00	0.00	0.00	1326.11	2740.62	2740.62	4597.16	4597.16	5009.73	5009.73
16699.10	16699.10	16699.10	16699.10	16699.10	0.00	0.00	0.00	4420.35	9135.39	9135.39	15323.88	15323.88	16699.10	16699.10
0.00	0.00	0.00	0.00	0.00	447.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
326.70	326.70	326.70	326.70	326.70	276.83	326.70	326.70	326.70	326.70	326.70	326.70	326.70	326.70	326.70
155.10	155.10	155.10	155.10	155.10	0.00	155.10	155.10	155.10	155.10	155.10	155.10	155.10	155.10	155.10
189.20	189.20	189.20	189.20	189.20	77.25	189.20	189.20	189.20	189.20	189.20	189.20	189.20	189.20	189.20
232.10	232.10	232.10	232.10	232.10	364.57	232.10	232.10	232.10	232.10	232.10	232.10	232.10	232.10	232.10
199.90	199.90	199.90	199.90	199.90	1094.35	199.90	199.90	199.90	199.90	199.90	199.90	199.90	199.90	199.90
1213.30	1213.30	1213.30	1213.30	1213.30	2442.28	1213.30	1213.30	1213.30	1213.30	1213.30	1213.30	1213.30	1213.30	1213.30
4044.33	4044.33	4044.33	4044.33	4044.33	8140.92	4044.33	4044.33	4044.33	4044.33	4044.33	4044.33	4044.33	4044.33	4044.33
13920.24	13920.24	13920.24	13920.24	13920.24	-8955.01	-4448.77	-4448.77	413.62	5600.16	5600.16	12407.50	12407.50	13920.24	13920.24
3796.43	3796.43	3796.43	3796.43	3796.43	-2442.26	-1213.30	-1213.30	112.80	1527.32	1527.32	3383.86	3383.86	3796.43	3796.43
3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
12318.80	12318.80	12318.80	12318.80	12318.80	-7924.79	-3936.96	-3936.96	366.03	4955.90	4955.90	10980.09	10980.09	12318.80	12318.80
3359.67	3359.67	3359.67	3359.67	3359.67	-2161.31	-1073.72	-1073.72	99.83	1351.61	1351.61	2994.57	2994.57	3359.68	3359.67
3008.00	3008.00	3008.00	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50	3783.50
1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
948.72	948.72	948.72	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32	1193.32
4743.62	4743.62	4743.62	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58	5966.58
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45	105.45
85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50	85.50
63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32	63.32
84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73	84.73
322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05	322.05
1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25	1610.25
626.67	626.67	626.67	871.27	871.27	871.27	871.27	871.27	871.27	871.27	871.27	871.27	871.27	871.27	871.27
554.58	554.58	554.58	771.03	771.03	771.03	771.03	771.03	771.03	771.03	771.03	771.03	771.03	771.03	771.03

Table 4. Benefits and costs: silvopastoral system.

Revenue and Costs: Semenyih (25 years)		Year									
		1	2	3	4	5	6	7	8	9	10
1) Timber											
A) Yield (cu.m./ha)		0	0	0	0	0	0	0	183.4	0	0
Unit price FOB (RM/cu.m.)							0.00	479.56	609.04	609.04	609.04
Total hectarage (ha)		5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Revenue (RM)		0	0	0	0	0	0	0	656779.4	0	0
2) Cover-crop											
Yield (kg/ha)		500	700	700	700	700	700	700	700	700	700
Unit Price (RM/kg)		1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Total hectarage (ha)		2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Revenue (RM)		2043.36	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704
Total Sales Revenue (RM)		2043.36	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	659640.1	2860.704	2860.704
B) Costs (RM)											
Salaries		9393.77	13044.00	12560.00	20217.50	10000.00	3000.00	3000.00	3000.00	3000.00	3000.00
Fringe Benefits		2089.00	2880.00	2777.00	3505.00	1500.00	1000.00	1000.00	1000.00	1000.00	1000.00
Travel		0.00	3605.11	4507.89	5532.48	3000.00	1000.00	600.00	600.00	600.00	600.00
Material and Service		2013.40	5425.68	39838.02	46382.16	5000.00	5000.00	3000.00	3000.00	3000.00	3000.00
Total Cost (RM)		13496.17	24954.79	59682.91	75637.14	19500.00	10000.00	7600.00	7600.00	7600.00	7600.00
CPI (1990 = 1.00)		0.90	1.00	1.42	1.52	1.22	1.13	1.13	1.13	1.13	1.13
Net Revenue (RM)		-11452.81	-22094.09	-56822.21	-72776.44	-16639.30	-7139.30	-4739.30	652040.17	-4739.30	-4739.30
Net Revenue (RM) at constant price relative to 1990		-12725.34	-22094.09	-40015.64	-47879.23	-13638.77	-6317.96	-4194.07	577026.70	-4194.07	-4194.07
Investment:	Setana	597.98	5371.42	39439.64	45918.34	4950.00	4950.00	2970.00	2970.00	2970.00	2970.00
	Timber	1479.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating:	Setana	3410.38	5800.15	5893.93	8688.73	4306.50	1485.00	1366.20	1366.20	1366.20	1366.20
	Timber	8439.84	14353.90	14585.99	21502.41	10657.50	3675.00	3381.00	3381.00	3381.00	3381.00
Working Capital:	Setana	2789.95	3874.07	3730.32	6004.60	2970.00	891.00	891.00	891.00	891.00	891.00
	Timber	6904.42	9587.34	9231.60	14859.86	7350.00	2205.00	2205.00	2205.00	2205.00	2205.00
Subtotal		23622.42	38986.87	72881.49	96973.94	30234.00	13206.00	10813.20	10813.20	10813.20	10813.20

The criterion for choice is to invest in any agroforestry project in which IRR is greater than the opportunity cost of capital.

Benefit–cost ratio (BCR)

BCR ratio is the ratio of the summed discounted benefits over the summed discounted costs. The formula can be written as:

$$\text{BCR} = \sum_{t-0}^{n} \frac{\dfrac{B_t}{(1+i)^t}}{\dfrac{C_t}{(1+i)^t}}$$

The criterion for choice is to invest in any agroforestry project options in which BCR ratio is greater than one.

Results

The base case results of the economic analysis are shown in Table 7. In general, agroforestry systems for livestock production on tin tailings are economically viable. The NPVs are all positive, RM146 per ha and RM219 per ha for agrosilvopastoral and silvopastoral systems, respectively. The values of IRRs are greater than the marginal economic opportunity cost of capital in 1984, 13% (Veitch 1986). However, the IRR for agrosilvopastoral system is only slightly higher than the marginal economic cost of capital. The values of BCR are greater than one, 1.59 and 3.22 for agrosilvopastoral and silvopastoral systems, respectively. The large-scale agroforestry systems on tin tailings for livestock production appear to be economically justified under the present practice. Silvipastoral system is found to be more economically viable compared to agrosilvopastoral system.

A sensitivty analysis was also carried out to determine the effects of changing certain variables on NPV. Three variables were selected: benefits, costs, and discount rates. The benefits and costs were either increased or decreased at the 10 and 20% interval. Discount rates were either reduced or increased to 8%, 10%, 12%, 14%, and 16%. Tables 8–10 present net present values (NPVs) for sensitivity analysis for both systems.

NPVs were all positive with respect to changes in benefits and costs. The lowest NPVs occurs when benefits decrease by 20% and costs increase by 20%.

At various interest rates, all NPVs were positive for the silvopastoral system. The maximum discount rate for feasibility is more than 16%. However, in the case of the agrosilvopastoral system, NPV was nega-

Table 4. (continued)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04	609.04
5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
0	0	0	0	290789.8	0	0	0	59089.05	0	111732.0	0	187652.5	0	0
700	700	700	700	700	700	700	700	700	700	700	700	700	700	700
1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704	2860.704
2860.704	2860.704	2860.704	2860.704	293650.5	2860.704	2860.704	2860.704	61949.76	2860.704	114592.7	2860.704	190513.2	2860.704	2860.704
3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00	600.00
3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00	3000.00
7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00	7600.00
1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
-4739.30	-4739.30	-4739.30	-4739.30	286050.50	-4739.30	-4739.30	-4739.30	54349.76	-4739.30	106992.75	-4739.30	182913.24	-4739.30	-4739.30
-4194.07	-4194.07	-4194.07	-4194.07	253142.04	-4194.07	-4194.07	-4194.07	48097.14	-4194.07	94683.85	-4194.07	161870.12	-4194.07	-4194.07
2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00	2970.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20	1366.20
3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00	3381.00
891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00	891.00
2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00	2205.00
10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20	10813.20

tive at 16 %. Therefore, the maximum discount rate for feasibility is no greater than 16 %.

Discussion

The silvopastoral system is more profitable than the agrosilvopastoral system because of better resource utilisation. For instance, less fertilizer is used, but sufficient for a tree to grow vigorously. Labour cost is also less because of less activity involved in the silvopastoral system. As such, cost reduction is possible when input level is closely monitored and maintained at a minimum level.

This study does not imply necessarily that agroforestry systems for livestock production are the best use of tin tailings. Even though the results obtained from this study indicate that NPVs are positive, some other factors could play an important role. Agroforestry practices should not be used as a basis for rehabilitating tin tailings at all locations at all times. Changes in prices and costs might indicate bias against other alternative land uses.

The premises on which agroforestry systems are based are biological and socioeconomic (Nair 1982). The results in this study show that these criteria are met. The species chosen for an agroforestry project on tin tailings depends on the extent of the adverse characteristics of the area. If properly selected the combination of crops and animals will provide better yields.

Agroforestry has a great potential to rehabilitate idle or degraded land such as tin tailings. The results from this study confirm that silvopastoral and agrosilvopastoral systems are economically justified. However, it should be pointed out that other alternative agroforestry practices are important. Fish farming, pond culture, cage culture, culture of ornamental fish, recreational fisheries and culture of aquatic weeds have been practiced on tin tailings (Ang 1990). Also, silvofishery practice (agriculture farming systems in combination with livestock and fish) has been successfully implemented (Kho et al. 1979). Thus, there is a need to evaluate various alternative agroforestry practices in order to maximise the economic returns from tin tailings.

One of the most important factors to consider is suitability of species on tin tailings. This is because of limited water level and competitive intake among species in tin tailings. Trees with deep and spreading root systems are suitable because they are capable of exploiting larger soil volume and tapping nutrients and water intake.

Table 5. Economic budget: agrosilvopastoral system.

Economic budget for Batang Berjuntai (10 ha)		Year									
		1	2	3	4	5	6	7	8	9	10
Benefits: with project											
Agricultural crops revenue		0.00	0.00	0.00	35499.50	67300.05	65556.03	67221.87	101570.99	105877.57	97764.72
Timber revenue		0.00	0.00	0.00	0.00	0.00	0.00	0.00	192265.65	0.00	0.00
Livestock revenue		0.00	0.00	567.90	766.67	690.00	485.92	653.68	904.92	1221.24	1709.73
Salvage value											
Subtotal		0.00	0.00	567.90	36266.17	67990.05	66041.94	67875.56	294741.56	107098.81	99474.45
Benefits: without project											
Sand sales: subtotal		651315.79	475961.54	152777.78	137500.00	123750.00	87147.89	81414.47	101434.43	109513.27	109513.27
Incremental benefits		-651315.79	-475961.54	-152209.88	-101233.83	-55759.95	-21105.95	-13538.92	193307.13	-2414.47	-10038.82
Costs: with project											
Investment:	agricultural crops	43440.00	0.00	99.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	timber	15003.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	livestock	13146.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	814.16	0.00
Subtotal		71590.25	0.00	99.14	0.00	0.00	0.00	0.00	0.00	814.16	0.00
Operating:	agricultural crops	65212.63	21432.77	9981.32	4920.40	5312.87	2630.65	3175.86	2951.12	2711.56	2813.45
	timber	33699.47	5270.19	1069.44	246.17	536.55	503.56	628.62	516.39	511.06	743.36
	livestock	33962.53	10328.77	4823.75	2910.27	1302.72	690.65	514.95	766.16	745.77	745.77
Subtotal		132874.63	37031.73	15874.52	8076.83	7152.14	4024.85	4419.42	4233.68	3968.39	4302.58
Production:	agricultural crops	13725.36	9634.16	2622.02	1033.46	1068.45	589.13	756.56	784.71	668.45	596.95
	timber	11494.74	4518.72	535.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	livestock	523.09	555.54	122.67	110.40	99.36	64.79	30.26	37.70	40.71	40.71
Subtotal		25743.19	14708.42	3280.06	1143.86	1167.81	753.92	786.82	822.42	709.16	637.65
SUBTOTAL		230208.08	51740.15	19253.71	9220.69	8319.95	4778.77	5206.24	5056.10	5491.71	4940.24
Costs: without project											
Investment		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production		208681.58	152498.08	48950.00	44055.00	39649.50	27922.18	26085.20	32499.59	35088.05	35088.05
Subtotal		208681.58	152498.08	48950.00	44055.00	39649.50	27922.18	26085.20	32499.59	35088.05	35088.05
Incremental costs:investment		71590.26	0.00	99.14	0.00	0.00	0.00	0.00	0.00	814.16	0.00
	operating	132874.63	39031.73	15874.52	8076.83	7152.14	4024.85	4419.42	4233.68	3968.39	4302.58
	production	-182938.39	-137789.66	-45669.94	-42911.14	-38481.69	-27168.27	-25298.38	-31677.77	-34378.89	-34450.40
Incremental costs		21526.50	-100757.93	-29696.29	-34834.31	-31329.55	-23143.42	-20878.95	-27443.49	-29596.36	-30147.81
With project net benfits		-230208.08	-51740.15	-18685.81	27045.48	59670.10	61263.17	62669.31	289685.46	101607.10	94534.22
Without project net benefits		442634.21	323463.46	103827.78	93445.00	84100.50	59225.70	553290.28	68934.84	74425.22	7425.22
Incremental net benefit		-672842.29	-375203.61	-122513.59	-66399.52	-244.30.40	2037.47	7340.04	220750.62	27181.86	20108.99

Table 5. (continued)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
99117.35	102615.52	106113.70	106236.87	100173.36	85012.24	85012.24	85012.24	86186.78	87437.56	87437.56	89080.52	89080.52	89445.63	89445.63
0.00	0.00	0.00	0.00	91905.75	0.00	0.00	0.00	18675.43	0.00	35313.54	0.00	59306.64	0.00	0.00
1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73	1709.73
100827.08	104325.26	107823.43	107946.60	193788.85	86721.97	86721.97	86721.97	106570.95	89147.30	124460.84	90790.26	150098.90	91155.36	95580.14
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100827.08	104325.26	107823.43	107946.60	193788.85	86721.97	86721.97	86721.97	106570.95	89147.30	124460.84	90790.26	150098.90	91155.36	95580.14
0.00	0.00	0.00	0.00	0.00	396.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	929.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	814.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
929.20	0.00	0.00	0.00	0.00	396.44	814.16	0.00	0.00	0.00	929.20	0.00	0.00	0.00	0.00
2813.45	2813.45	2813.45	2813.45	2813.45	3441.77	2813.45	2813.45	2813.45	2813.45	2813.45	2813.45	2813.45	2813.45	2813.45
743.36	371.68	1077.88	743.36	371.68	1997.79	613.27	371.68	371.68	743.36	743.36	371.68	1077.88	557.52	650.44
745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77	745.77
5557.01	3930.90	4637.10	4302.58	3930.90	4662.36	4172.50	3930.90	3930.90	4302.58	5557.01	3930.90	4637.10	4116.74	4209.68
596.95	596.95	596.95	596.95	596.95	552.81	596.95	596.95	596.95	596.95	596.95	596.95	596.95	596.95	596.95
0.00	0.00	0.00	0.00	0.00	464.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71	40.71
637.65	637.65	637.65	637.65	637.65	1058.12	637.65	637.65	637.65	637.65	637.65	637.65	637.65	637.65	637.65
7123.87	4568.56	5274.75	4940.24	4568.56	6116.92	5624.31	4568.56	4568.56	4940.24	7123.87	4568.56	5274.75	4754.40	4847.32
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
929.20	0.00	0.00	0.00	0.00	396.44	814.16	0.00	0.00	0.00	929.20	0.00	0.00	0.00	0.00
5557.01	3930.90	4637.10	4302.58	3930.90	4662.36	4172.50	3930.90	3930.90	4302.58	5557.01	3930.90	4637.10	4116.74	4209.66
637.65	637.65	637.65	637.65	637.65	1058.12	637.65	637.65	637.65	637.65	637.65	637.65	637.65	637.65	637.65
7123.87	4568.56	5274.75	4940.24	4568.56	6116.92	5624.31	4568.56	4568.56	4940.24	7123.87	4568.56	5274.75	4754.40	4847.32
93703.22	99756.70	102548.68	103006.36	189220.29	80605.05	81097.66	82153.41	102002.39	84207.06	117336.97	86221.70	144824.14	86400.95	90732.82
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93703.22	99756.70	102548.68	103006.36	189220.29	80605.05	81097.66	82153.41	102002.39	84207.06	117336.97	86221.70	144824.14	86400.96	90732.82

Table 6. Economic budget: silvopastoral system.

Economic budget for Semenyih (8 ha)		Year									
		1	2	3	4	5	6	7	8	9	10
Benefits: with project											
Cover-crop revenue		2270.40	2860.70	2014.58	1882.04	2344.84	2531.60	2531.60	2531.60	2531.60	2531.60
Timber revenue		0.00	0.00	0.00	0.00	0.00	0.00	0.00	51220.77	0.00	0.00
Salvage Value											
Subtotal		2270.40	2860.70	2014.58	1882.04	2344.84	2531.60	2531.60	583752.36	2531.60	2531.60
Benefits: without project											
Sand sales: subtotal		137500.00	123750.00	87147.89	81414.47	101434.43	109513.27	109513.27	109513.27	0.00	0.00
Incremental benefits		-135229.60	-120889.30	-85133.31	-79532.43	-99089.59	-106981.68	-106981.68	474239.09	2531.60	2531.60
Costs: with project											
Investment:	cover-crop	664.42	1611.43	8332.32	9062.83	1217.21	1314.16	788.50	788.50	788.50	788.50
	timber	1644.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal		2308.70	1611.43	8332.32	9062.83	1217.21	1314.16	788.50	788.50	788.50	788.50
Operating:	cover-crop	3789.31	5800.15	4150.66	5716.27	3529.92	1314.16	1209.03	1209.03	1209.03	1209.03
	timber	9377.60	14353.90	10271.83	14146.32	8735.66	3252.21	2992.04	2992.04	2992.04	2992.04
Subtotal		13166.91	20154.04	14422.48	19862.59	12265.57	4566.37	4201.06	4201.06	4201.06	4201.06
Production:	cover-crop	3099.94	3874.07	2626.99	3950.39	2434.43	788.50	788.50	788.50	788.50	788.50
	timber	7671.58	9587.34	6501.13	9776.23	5054.59	1951.33	1951.33	1951.33	1951.33	1951.33
Subtotal		10771.52	13461.41	9128.11	13726.82	8459.02	2739.82	2739.82	2739.82	2739.82	2739.82
SUBTOTAL		26247.13	35226.88	31882.91	42652.04	21941.80	8620.35	7729.38	7729.39	7729.38	7729.38
Costs: without project											
Investment		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operating		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production		44055.00	39649.50	27922.18	26085.20	32499.59	35088.05	35088.05	35088.05	0.00	0.00
Subtotal		44055.00	39649.50	27922.18	26085.20	32499.59	35088.05	35088.05	35088.05	0.00	0.00
Incremental costs:investment		2308.70	1611.43	8332.32	9062.83	1217.21	1314.16	788.50	788.50	788.50	788.50
	operating	13166.91	20154.04	14422.48	19862.59	12265.57	4566.37	4201.06	4201.06	4201.06	4201.06
	production	-33283.48	-26188.09	-18794.07	-12358.58	-24040.57	-32348.23	-32348.23	-32348.23	2739.82	2739.82
Incremental costs		-17807.87	-4422.62	3960.73	16566.84	-10557.79	-26467.70	-27358.67	-27358.67	7729.38	7729.38
With project net benefits		-23976.73	-32366.17	-29868.33	-40770.00	-19596.96	-6088.76	-5197.78	576022.98	-5197.78	-5197.78
Without project net benefits		93445.00	84100.50	59225.70	55329.26	68934.84	74425.22	74425.22	74425.22	0.00	0.00
Incremental net benefit		-117421.73	-116466.67	-89094.04	-96099.27	-88531.80	-80513.98	-79623.01	501597.76	-5197.78	-5197.78

Table 6. (continued)

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60	2531.60
0.00	0.00	0.00	0.00	257336.11	0.00	0.00	0.00	52291.20	0.00	98877.91	0.00	166064.19	0.00	0.00
2531.60	2531.60	2531.60	2531.30	259867.70	2531.60	2531.60	2531.60	54822.81	2531.60	101409.51	2531.60	168595.78	2531.60	7531.60
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2531.60	2531.60	2531.60	2531.60	259867.70	2531.60	2531.60	2531.60	54822.80	2531.60	101409.51	2531.60	168595.78	2531.60	7531.60
788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50
1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03	1209.03
2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04	2992.04
4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06
788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50
1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33	1951.33
2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82
7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50	788.50
4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06	4201.06
2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82	2739.82
7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38	7729.38
-5197.78	-5197.78	-5197.78	-5197.78	252138.32	-5197.78	-5197.78	-5197.78	47093.42	-5197.78	93680.13	-5197.78	160866.40	-5197.78	-197.78
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-5197.78	-5197.78	-5197.78	-5197.78	252138.32	-5197.78	-5197.78	-5197.78	47093.42	-5197.78	93680.13	-5197.78	160866.40	-5197.78	-197.78

Environmental benefits would be expected to be significant from agroforestry practice on tin tailings. Since harvesting of agricultural crops is conducted at different times in a year, protection of the soil surface against the impact of rain drops can be maximised. Tree roots help to hold soil and also form pores to allow rainwater to be absorbed, filtered and stored in the ground, especially on slime fractions. These help to improve soil condition in tin tailings. For instance, Lim et al. (1990) reported improvements in soil pH and P, K and Mg content after 5 years of oil palm cultivation on tin tailings.

Even though the results obtained in this study are promising, there are some caveats which must be considered for future development. Data on growth and yield for timber species and agricultural crops were estimated from a simulation model or from data collected in previous research. Since tree growth is subject to various ecological, biological and environmental conditions, these might have some impact on revenue. Further study on growth and yield for various species planted in tin tailings is needed.

Table 7. Results of benefit–cost analysis.

Agroforestry system	NPV (RM/ha)[a]	IRR (%)	BCR
Agrosilvopastoral	145.62	14.20	1.59
Silvopastoral	218.82	34.30	3.22

[a] RM = Ringgit Malaysia (US$1.00 = RM2.57 in 1993).

Table 8. Sensitivity of NPV resulting from changes in benefits and costs, agrosilvopastoral system (RM/ha).

Change in costs	Change in benefits (%)				
	–20	–10	0	+10	+20
–20	103.25	144.25	185.24	226.23	267.22
–10	83.44	124.44	165.43	206.42	247.41
0	63.63	104.62	145.62	186.61	227.60
+10	43.82	84.81	125.81	166.80	207.79
+20	24.01	65.00	106.00	146.99	187.98

Table 9. Sensitivity of NPV resulting from changes in benefits and costs, silvopastoral system (RM/ha).

Change in costs	Change in benefits (%)				
	–20	–10	0	+10	+20
–20	170.84	204.16	237.48	270.81	304.13
–10	161.50	194.83	228.15	261.47	294.80
0	152.17	185.85	218.12	252.14	285.47
+10	142.84	176.17	209.49	242.81	276.14
+20	133.51	166.83	200.16	233.48	266.80

Table 10. Sensitivity of NPV at different discount rates (RM/ha).

System	Discount rate (%)				
	8	10	12	14	16
Agrosilvopastoral	258.74	145.62	64.18	5.02	–38.31
Silvopastoral	281.69	218.12	170.73	133.45	104.21

A costing study under various agroforestry systems in different areas is also required. Such a study would be timely because no intensive research has been carried out to investigate the economics of agroforestry practices. Some of the data used in this study were simply assumed, based on information from previous research. Because any economic analysis will depend heavily on reliable data, information on costs, prices, and yield is critical.

Conclusion

Agroforestry systems on tin tailings are economically viable for livestock production. With intensive research and improved technology, the economic returns on tin tailings can be maximised provided that market potential is available. Since tin tailings in Peninsular Malaysia are sited adjacent to major urban centres, the future for agroforestry practices for livestock production is promising. Other combinations of fast growing timber species with agriculture crops and livestock should be exploited. In addition, environmental benefits derived from agroforestry systems on tin tailings should be identified and quantified to provide a comprehensive economic appraisal. Large-scale agroforestry systems on tin tailings could be carried out by private investors.

References

Ang, K.H. 1990. Potentials of aquaculture. In: National Seminar on Ex-mining Land and Bris Soil. 11–15 October 1990, Kuala Lumpur.

Birkenshaw, F. 1931. Reclaiming old mining land for agriculture. Malayan Agriculture Journal, 19, 470–476.

Chan, Y.K. 1990. Tin mining land: an overview of the current situation in Peninsular Malaysia. In: National Seminar on Ex-mining Land and Bris Soil. 11–15 October, 1990, Kuala Lumpur.

Gittinger, J.P. 1982. Economic analysis of agriculture projects. Baltimore, MD, USA, Johns Hopkins University Press, 505 p.

Kho, B.L., Chai, T.B. and Vimala, P. 1979. Research towards farming systems on bris and tin-tailings. In: Hashim Abd. Wahab, Ong, C.A., Siti Petimah Hj. Hassan, Chan, S.K., Ramli Mohd. Nor and Shaaban Shahar, ed., Proceedings of Conference on Research in Development of Smallholder Farming, Serdang, Malaysia, 84–93.

Lim, K.H., Hussain, E. and Pillai, K.R. 1990. Trial on tin tailings. In: National Seminar on Ex-Mining Land and Bris Soil. 11–15 October 1990, Kuala Lumpur.

Lim, K.H., Maene, L. Maesschalck, G.G. and Wan Sulaiman Wan Harun. 1981. Reclaimation of tin tailings in Malaysia. Technical Bulletin of the Faculty of Agriculture, Universiti Pertanian Malaysia, Serdang, Malaysia, 61 p.

Maene, LM., Connor, C.L. and Yaacob, O. 1977. Food production on tin tailings in the Seri Kembangan-Balakong area. Food and Agriculture Malaysia, 113–123.

Mitchell, B.A. 1957. Malayan tin-tailings—prospects of rehabilitation. Malayan Forester, 20, 181–186.

Nair, P.K.R. 1982. Agroforestry: a sustainable land use system for the fragile ecosystems in the tropics. Malayan Nature Journal, 35, 109–123.

Nik Muhamad, N. M. 1990. The role of agroforestry in the rehabilitation of the ex-mining land. In: National Seminar on Ex-mining Land and Bris Soil. 11–15 October, Kuala Lumpur.

Palaniappan, V.M. 1972. History, flora and edaphology of tin tailings areas around Kuala Lumpur. Tropical Ecology, 13, 202–225.

— 1974. Ecology of tin tailings areas: plant communities and their succession. Journal of Applied Ecology, 11, 133–150.

Reid, J.A. 1956. Plants of the tin tailings. Malayan Nature Journal, 12, 3.

Shamsuddin, J., Nik Mokhtar and Paramanathan, S. 1986. Morphology, mineralogy and chemistry of ex-mining land in Ipoh, Perak. Pertanika, 9, 89-97.

Veitch, M.D. 1986. National Parameters for Project Appraisal in Malaysia. Economic Planning Unit, Kuala Lumpur, Malaysia. Vols 1–4.

Nutritional and Anti-nutritional Values of Multipurpose Trees Used in Agroforestry Systems

P.O. Osuji*

Abstract

Multipurpose trees improve the usage of poor quality roughages. In addition to their feed value, they contribute to environmental quality, e.g. by conserving soil. However, some multipurpose trees contain anti-nutritional factors which reduce their nutritive value. Trials in which gas production and rumen degradation rates were studied indicated that multipurpose trees increased the rates of degradation of fibrous feeds, their rate of passage and the efficiency of microbial protein supply. The effects of extracts of several multipurpose trees on pure cultures of *Fibrobacter succinogenes*, *Ruminococcus flavefaciens* and *R. albus* are reported. *Acacia angustissima* suppressed the growth of *Ruminococcus* and slowed the growth of other bacteria. Dry matter yields were significantly increased when leucaena or gliricidia were intercropped with maize/cassava or Napier grass in agroforestry systems. It is concluded that the improved milk production resulting from such systems has many social benefits for smallholders and their families.

INADEQUATE year-round nutrition is probably the most important factor contributing to low animal output in subSaharan Africa where livestock depend on unimproved native pastures and crop residues. This necessitates supplementation. Among the most promising forage supplements are leguminous fodder trees, or multipurpose trees. At least 75% of the trees and shrubs in Africa are browsed by domestic and game animals (French 1949; Le Houerou 1980a,b).

Fodder trees play an important role in agroforestry systems as they offer advantages over herbaceous species by their superior persistence, higher dry matter yields, better resistance to mismanagement and a capacity to retain high-quality foliage under stress conditions. They provide fertilizer in the form of mulch, curb erosion, conserve moisture and build up soil fertility. These qualities make multipurpose trees very important in the preservation and restoration of fragile environments. Some fodder trees may be agronomically successful, but unsuitable for livestock due to high levels of anti-nutritive factors, e.g. polyphenolics mostly found in the leaves (Lowry 1990), that can significantly reduce nutritive value (Reed et al. 1990). There is a higher incidence of alkaloids in tropical than in temperate plants (Levin and York, 1978). Since many browse plants are toxic to animals at certain times of the year or to animals under stress (Skerman et al. 1988), there is a need to evaluate the anti-nutritive quality of fodder trees, even though nutritive value is not easily predicted from chemical analyses of such secondary plant compounds as phenolics (Wilson 1977; Wilson and Harrington 1980).

Research on the effects of plant toxins and anti-nutritive factors (e.g. saponnins) on rumen microorganisms, mammalian enzyme systems and on the environment is required. Forage plant toxins have been reviewed by Keeler et al. (1978), Cheeke and Hull (1985) and Seawright et al. (1985). Hegarty (1964) discussed biological and chemical methods to study plant toxins. These methods are usually tedious and in some instances (e.g. biological methods) require sizeable quantities of the material to be fed, even if only to laboratory animals. For rapid assessment and initial screening of fodder trees, a simple tool is needed. The International Livestock Centre for Africa (ILCA) uses a modification of the in vitro gas production technique (Menke et al. 1979; Krishna-

* International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

moorthy et al. 1991; Hillman et al. 1993) and the nylon bag degradation method (Ørskov and McDonald 1979; Blummel and Ørskov 1993) to assess fodder trees. These methods are quick and need very small samples (< 50 g), making them attractive for the first stages of germplasm evaluation of single rows or a few plants. Between genera, intra-specific and accessional variations in nutritive value are important (Siaw et al. 1993a) to establish a general index of their forage value.

The Role of Multipurpose Trees in Fibre Utilisation

Roughages fed to ruminants by smallholders are bulky, high in fibre (NDF [neutral detergent fibre] > 700 g/kg), slowly degraded (<3%/hour) and low in nitrogen (<70g/kgCP) and minerals e.g. sulfur. These characteristics result in low dry matter intake and thus the need for supplementation. Because smallholders may be unable to afford physical and chemical treatment of fibrous feeds, alternative feeding strategies are required. Most smallholders, however, can afford to grow multipurpose trees principally for soil management but also as feed supplements to animals (Table 1).

Microbial adhesion, particle size reduction, favourable rumen environment (pH>6.2, NH_3>3.5 mmol/L), passage rates of both particulate and liquid digesta, roughage fermentation rate and VFA production, adequate supply of iso-acids for microbial protein production and by-pass protein supply are major determinants of the intake, utilisation of poor quality roughages and the composition of the excreta used in farming. Supplementation with multipurpose trees could influence these conditions, e.g. relatively high levels of some minerals have been found in the faeces of sheep supplemented with multipurpose trees.

Perennial tropical browse legumes are sustainable in small farming systems, high in crude protein (leaves and fruits) and drought tolerant (Topark-Ngarm and Gutteridge 1990). ILCA's gene bank has assembled numerous accessions of both native and exotic tropical legume species (Hanson and Lazier 1988) that are being assessed agronomically (Siaw et al. 1993b), and for feed value (Woodward and Reed 1989; Tanner et al. 1990; Reed et al. 1990; Wiegand 1991; Khalili and Varvikko 1992; Varvikko et al. 1992). Nutrition research tends to assess and rank species/accessions using animal responses (intake, digestibility, growth rate etc.) which is onerous if the

Table 1.Chemical characteristics of multipurpose trees.

	Low (g/kg DM)	High (g/kg DM)
Nitrogen	*Dichrostachys cinerea* (13.9)	Leucaena (40.5)
Fibre (NDF)	Sesbania (206)	*D. cinerea* (498)
NDF-N	Sesbania (2.4)	Tagasaste (9.2)
Soluble tannins	*Carissa edulis* (21.5)	*A. siberiana* (327)
Condensed tannins		
(500 nm/g NDF)	Sesbania (13)	Tagasaste (56)
Phosphorous	Vernonia (0.7)	Sesbania (2.7)
Calcium	Tagasaste (10.5)	Leucaena (20.0)
Sulphur	Tagasaste (1.5)	Leucaena (2.3)
N degradation rate (mg/kg/hour)		
Iron	Sesbania (360)	Tagasaste (520)
Manganese	Leucaena (66)	Tagasaste (200)
Copper	Leucaena (13)	Vernonia (20)
Zinc	Leucaena (19)	Tagasaste (39)

NDF = Neutral detergent fibre.
NDF-N = Nitrogen bound to NDF.

widely varied accessions are to be evaluated individually.

Work at ILCA has examined gas production and *in sacco* degradation of leguminous browses, particularly of the *Sesbania* genera, in relation to their tannin and other compositional attributes. Principal component and cluster analyses are used to test the hypothesis that gas production, degradation characteristics, macro-constituents and tannins are of equal classificatory value (Siaw et al. 1993a; Nsahlai et al. 1994). This work has been extended to the manipulation of rumen environments using fodder trees to improve fibre degradation, microbial protein supply (Osuji et al. 1993; Umunna et al. 1994) and rumen digesta kinetics (Bonsi et al. 1994). Tanniferous fodder trees have also been used to complex protein. The strategy is to identify simple, fast and easy methods which are sufficiently discriminating to classify fodder tree germplasm, at an early stage, into groups so that groups rather than single species are studied in detail (Nsahlai et al. 1994). Previous work at ILCA on the role of fodder trees in farming systems was summarised by Jutzi et al. (1986), Woodward and Reed (1989) and in various Network Proceedings (Le Houerou 1980a; Reed et al. 1988; ARNAB 1989; Stares et al. 1992; Kategile and Adoutan 1993).

Anti-nutritional Factors in Multipurpose Trees

Many browses or multipurpose trees have evolved under different circumstances in various agroecological zones. These multipurpose trees contain compounds (e.g. saponnins, alkaloids, tannins, etc.), performing different functions for the plants themselves, e.g. protection against insects or wild animals. Similarly, many wild animals have developed special mechanisms for degrading some of these chemicals, indicating the importance of adaptation in the use of multipurpose trees. The phytochemistry and mode of action of most anti-nutritional factors are not fully understood. There are indications, however, that some have defaunation, bactericidal, or bacteriostatic qualities. Furthermore, poisons from multipurpose trees act either on the rumen microbes or on the host animal itself making the evaluation of multipurpose trees rather difficult. In many cases the rumen is capable of degrading many of the anti-nutritional components of multipurpose trees but sometimes rumen degradation can result in the production of toxic metabolites from innocuous compounds (Mackie and White 1990). A good example is acute bovine pulmonary poisoning due to the production of 3-methylindole from tryptophan (Carlson and Beerze 1984). The role of these plant toxins and their degradation products in modifying the environment is not known.

Results of studies from the ILCA laboratory indicate that several factors affect the interaction of multipurpose trees with rumen microbes. Four multipurpose trees, sesbania, leucaena, tagasaste and vernonia were evaluated using the *in sacco* method (Ørskov and MacDonald 1979). The rates of dry matter and N degradation varied significantly among the four trees. Sesbania was degraded most rapidly, vernonia relatively slowly. Both the fast degrading and the slow degrading multipurpose trees could be harnessed to nutritional advantage and may also affect the rate of production of greenhouse gases like methane and carbon dioxide. Results from several *in sacco* trials showed that the form (fresh or dry) of the multipurpose tree affected the rate of dry matter and N degradation. Fresh forms of the multipurpose trees were degraded much faster than the dry. The quantity of multipurpose tree fed also affects its utilisation. Both dry matter degradation and passage rates increased with increasing amounts of sesbania up to 245 g/hd/day and then declined. Improved or faster outflow rates may result in increased intake.

Multipurpose Trees and the Efficiency of Microbial Protein Supply

Enhanced fermentation of the roughages fed by smallholders ensures energy supply mainly as volatile fatty acids and, given the scarcity of protein in such systems, there is need to maximise the supply of microbial protein. Results from the ILCA laboratory indicate that multipurpose trees improve the rate of degradation of the basal feed, the passage rate of particulate matter and the efficiency of microbial protein production (Fig. 1). Rapidly degraded multipurpose trees like sesbania increase passage rate and the efficiency of microbial protein supply and are better supplements as demonstrated by reduced substitution of the basal roughage diet.

Multipurpose trees can be fed as leaves, leaves plus fruits or fruits alone. Sesbania leaves were compared with *Acacia albida* pods. The rate of degradation of the leaves was much higher than that of the *A. albida* pods. It was expected that the substitution rate would be lower with sesbania leaves. To the contrary, the rate was lower with the pods, suggesting that bulkiness of the multipurpose tree may be an important additional factor affecting the intake of fibrous feeds. When roughages of varying N content were supplemented with multipurpose trees, the degradation rate of the basal roughage increased with N content but the effect of the multipurpose tree supplement on roughage degradation rate was most marked in the basal roughage with the lowest level of N. This suggests that smallholders feeding native pastures and crop residues will benefit most by supplementing their animals with fodder trees, as the benefits from multipurpose tree supplementation are best with the poorest quality roughage.

Putting Anti-nutritional Factors to Good Use

Attempts have been made to harness anti-nutritional factors (e.g. tannins) to nutritional advantage. Oilseed cakes were fed in association with browses and only minor depressions in the rate of fermentation of oilseed cake were noticed. The changes due to this associative feeding of oilseed cakes and tanniferous browses on growth rate were small, even though both N and total organic matter intakes were significantly ($p<0.01$) improved.

The effect of multipurpose trees on mixed rumen microbes are different from those on pure cultures. In in vitro trials, *Sesbania sesban* reduced the number of protozoa suggesting that *S. sesban* may have defaunating properties. However, this was not confirmed in an in vivo trial at ILCA Debre Zeit Research Station where *S. sesban* was compared to *Medicago sativa*. Cross contamination may well have taken place.

The effects of extracts of vernonia, tagasaste, sesbania and *A. angustissima* on the growth of pure cultures of *Fibrobacter succinogenes*, *Ruminococcus flavefaciens* and *R. albus* were investigated. Vernonia, tagasaste and sesbania extracts affected the growth of *R. albus* by prolonging the lag phase. However, *A. angustissima*, at inclusion rates of 0.1, 0.2 and 0.3 mL, greatly suppressed the growth of *Ruminococcus* species (that are important for fibre digestion) and slowed the growth of others. Muller-Harvey et al. (1988) found that extracts of Ethiopian browses increased the lag time and reduced the growth rate of *Streptococcus bovis*; extracts from *Acacia nilotica* were particularly detrimental.

Gas production rates decreased substantially when some multipurpose trees were incubated in rumen fluid. *Acacia angustissima* suppressed fermentation

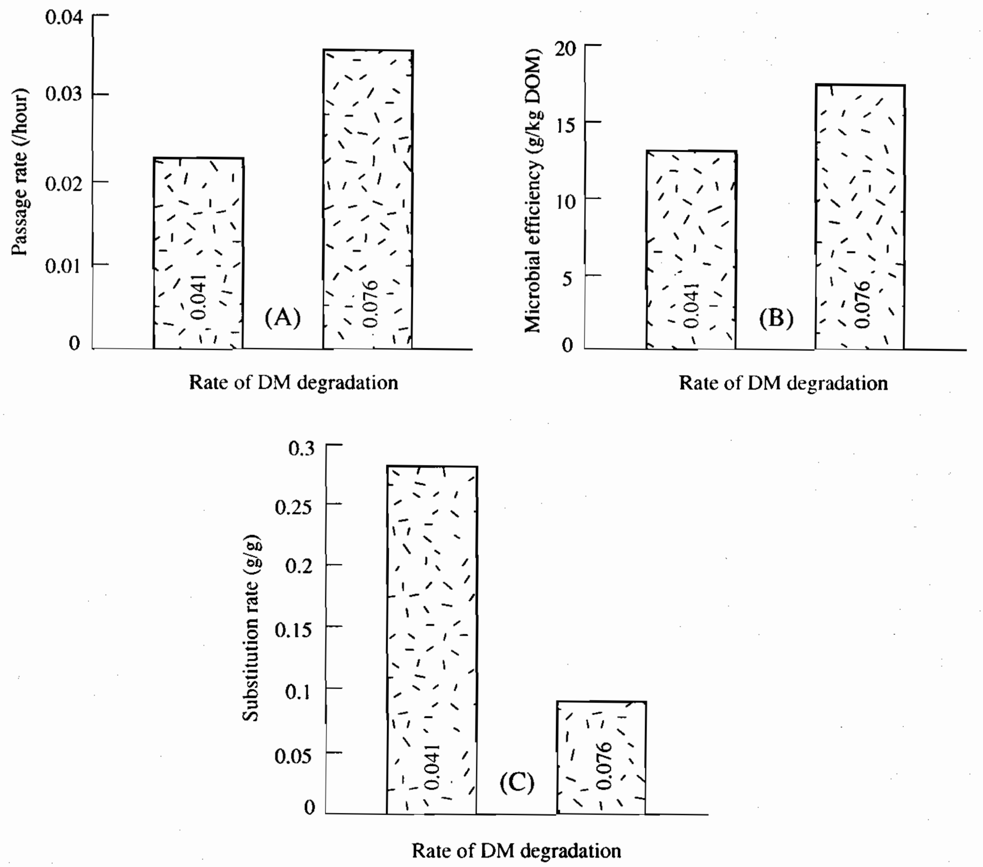

Fig. 1. Effect of rate of degradation of browses on (a) passage rate of particulate matter; (b) efficiency of microbial N supply; and (c) substitution rate.

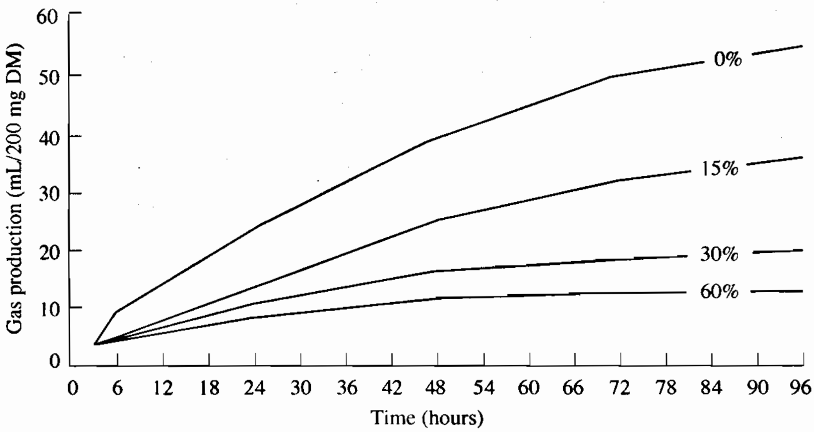

Fig. 2. Gas production (mL) over 96 hours incubation from different inclusion levels of *Acacia angustissima* with teff straw.

and the extent of suppression depended on the amount of multipurpose tree included (Fig. 2). The reverse was true for leucaena. These effects were further demonstrated in vivo when animals were fed *A. angustissima* or Tephrosia. The effect of anti-nutrition factors on dry matter intake could be quite drastic. Anti-nutrition factors depressed dry matter intake in sheep fed *A. angustissima* to such an extent that many of the animals died; sheep fed Tephrosia had massive rumen stasis.

Use of Multipurpose Trees in Agroforestry Systems

The nutritional and anti-nutritional qualities of multipurpose trees will not benefit smallholders unless attractive practical systems of integrating them into farm systems are available. In this regard, alley farming (an agroforestry system) contributes to fallow management, crop production, soil nutrient replenishment, soil conservation, and animal feed supply. It is particularly important to note the negative role of social institutions, e.g. land tenure rules, on the adoption of alley farming in certain parts of south-central Nigeria (Sumberg and Atta-Krah 1988; Kang et al. 1990).

Multipurpose trees have been grown in association with food crops or forage crops. In trials undertaken in support of smallholder milk production by ILCA in the subhumid coast of Kenya, both *Leucaena leucocephala* and *Gliricidia sepium* were intercropped with maize/cassava or Napier (*Pennisetum purpureum*) grass. Table 2 summarises four years data on leucaena intercropped with maize. Total dry matter yields were increased from 16.4 t/ha when Napier grass was grown alone to 29 t/ha for Napier plus leucaena plus manure slurry. The effects of nitrogen source (fertilizer or *Clitoria ternatea*) were also demonstrated. It is important to note the contribution of slurry, a potential water pollutant. Similarly, results from intercropping maize/cassava with gliricidia showed the benefits of the multipurpose trees. When crossbred dairy cows were supplemented with some of the leucaena produced from the intercropping trials, supplementation significantly improved ($p<0.01$) dry matter intake and milk yield and reduced body weight loss. Further gains were made ($p<0.01$) by feeding the leucaena along with 1 kg of maize bran. Improved milk production has a lot of social benefits for smallholders and their families.

Conclusion

Multipurpose trees contribute in many ways to soil management and conservation, and provide very valuable nutrients to animals. However, some multipurpose trees contain anti-nutritional factors which can be detrimental to animal production or could be harnessed to nutritional advantage. Research is needed on the use of multipurpose trees as livestock feed and in agroforestry systems. This work should aim at identifying rapid methods of evaluation, the role of anti-nutritional factors, particularly their effects on pure and mixed cultures of rumen microbes, and implications of plant toxins and their degradation products for the environment. Furthermore, methodologies for rapid assessment of multipurpose trees from the agronomic to the animal utilisation stages are needed.

Table 2. The effect of intercropping leucaena with maize on maize grain (and stover) dry matter yields (DM t/ha) (ILCA, Mombasa 1994).

Treatment			1990		1991	1992		1993	Total
Hedge	Mulch	Slurry	L	S	L	L	S	L	
–	–	–	2.7	1.0	1.4	1.0	0.6	1.5	8.2 (8.7)
+	+	–	3.3	0.7	1.8	3.0	0.6	1.5	10.9 (9.8)
+	–	+	3.4	0.6	0.9	0.9	1.1	1.9	8.8 (10.6)
+	+	+	4.2	1.0	2.1	3.7	2.0	3.3	16.3 (15.5)
75 kg N, 20 kg P			5.4	1.9	2.7	2.9	1.4	3.4	17.7 (15.6)
Mulch N yield (kg /ha)			99	92	70	109	26	63	

L = long rains.

S = short rains.

Acknowledgments

This paper was based on the multidisciplinary work of several ILCA scientists and graduate associates. In particular I would like to thank the following Dr W. Thorpe, Prof. N.N. Umunna, Dr I. Nsahlai, Dr J. Hanson, Dr H. Khalili, Dr O. Kurdi, and Mr El Hassan, Mr M. Bonsi, Mr Abule Ebro and Mr J. Johns.

References

ARNAB (African Research Network for Agricultural By-products) 1989. Overcoming constraints to the efficient utilization of agricultural by-products as animal feed. Proceedings of the Fourth Annual Workshop held at the Institute of Animal Research, Mankon Station, Bamenda, Cameroun, 20–27 October 1987. ARNAB, Addis Ababa, Ethiopia.

Blummel, M. and Ørskov, E.R. 1993. Comparison of in vitro gas production and nylon bag degradability of roughages in predicting intake in cattle. Animal Feed Science and Technology, 40, 109–119.

Bonsi, M.L.K., Osuji, P.O., Nsahlai, I.V. and Tuah, A.K. 1994. Graded levels of *Sesbania sesban* and *Leucaena leucocephala* as supplements to teff straw fed to Ethiopian Menz sheep. Animal Production, in press.

Carlson, J.R. and Beerze, R.G. 1984. Ruminal metabolism of plant toxins with emphasis on indolic compounds. Journal of Animal Science, 58, 1040–1094.

Cheeke, P.R. and Hull, L.R. 1985. Natural toxicants in feeds and poisonous plants. Westport, CT, USA, AVI Publishing Co. Inc.

French, M.H. 1949. Some use and misuse of shrubs and trees as fodder. East African Journal of Agriculture, 14, 157–165.

Hanson, J. and Lazier, J.R. 1988. Forage germplasm at the International Livestock Centre for Africa. In: PANESA (Pasture Network for Eastern and Southern Africa), African forage plant genetic resources, evaluation of forage germplasm and extensive livestock production systems. Proceedings of the Third Workshop held at the International Conference Centre, Arusha, Tanzania. 27–30 April 1987. Addis Ababa, Ethiopia, ILCA, 69–73.

Hegarty, M.P. 1964. Plant chemistry. In: Some concepts and methods in sub-tropical pasture research. Hurley, England, Commonwealth Bureau of Pastures and Field Crops, Bulletin 47, 154–158.

Hillman, H.K., Newbold, C.J. and Stewart, C.S. 1993. The contribution of bacteria and protozoa to ruminal forage fermentation in vitro, as determined by microbial gas production. Animal Feed Science and Technology, 42, 193–208.

Jutzi, S., Haque, I., McIntire J. and Stares, J.E.S., ed. 1986. Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 31 August–4 September 1987. Addis Ababa, Ethiopia, ILCA, 435 p.

Kategile, J.A. and Adoutan S.B., ed. 1993. Collaborative research on Sesbania in east and southern Africa. Proceedings of an AFRNET Workshop held in Nairobi, Kenya, 9–14 September 1991. Nairobi, Kenya, ILCA.

Kang, B.T., Reynolds, L. and Atta-Krah, A.N. 1990. Alley farming. Advances in Agronomy, 43, 315–359.

Keeler, R.F., Van Kampen, K.R. and James, L.F., ed. 1978. The effects of poisonous plants on livestock. New York, Academic Press.

Khalili, H. and Varvikko, T. 1992. Effect of replacement of concentrate mix by wilted sesbania (*Sesbania sesban*) forage on diet digestibility, rumen fermentation and milk production in Friesian × Zebu (Boran) crossbred cows fed low quality native hay. Animal Feed Science and Technology, 36, 275–286.

Krishnamoorthy, U., Steingass, H. and Menke, K.H. 1991. Preliminary observations on the relationships between gas production and microbial protein synthesis in vitro. Archives of Animal Nutrition, Berlin, 41(5), 521–526.

Le Houerou, H.N. 1980a. Browse in northern Africa. In: Le Houerou, H.N., ed., Browse in Africa. Addis Ababa, Ethiopia, ILCA, 55–82.

— 1980b. Chemical composition and nutritive value of browse in tropical west Africa. In: Le Houerou, H.N., ed., Browse in Africa. Addis Ababa, Ethiopia, ILCA, 261–297.

Levin, D.A. and York, B.M. 1978. The toxicity of plant alkaloids: an ecogeographic perspective. Biochemical Systems and Ecology, 6, 61–76.

Lowry, J.B. 1990. Toxic factors and problems: methods of alleviating them in animals. In: Devendra, C., ed., Shrubs and tree fodders for farm animals. IDRC Workshop Proceedings, Denpasar, Indonesia, 24–29 July 1989, 76–90.

Mackie, R.I. and White, B.A. 1990. Recent advances in rumen microbial ecology and metabolism: potential impact on nutrient output. Journal of Dairy Science, 73, 2971–2995.

Menke, K.H, Rabb, L., Salewski, A., Steingass, H., Fritz, F. and Schneider, W. 1979. The estimation of the digestibility and metabolizable energy content of ruminant feedingstuffs from the gas production when they are incubated with rumen liquor in vitro. Journal of Agricultural Science, Cambridge, 93, 217–222.

Muller-Harvey, I., McAllan, A.B., Theodorou, A.K. and Beever, D.E. 1988. Phenolics in fibrous crop residues and plants and their effects on the digestion and utilisation of carbohydrates and proteins in ruminants. In: Reed, J.D., Capper, B.S. and Neate, P.J.H., ed., Plant breeding and the nutritive value of crop residues. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 7–10 December 1987. Addis Ababa, Ethiopia, ILCA, 97–132.

Nsahlai, I.V., Siaw, D.E.K.A. and Osuji, P.O. 1994. The relationships between gas production and chemical composition of 23 browses of the genus *Sesbania*. Journal of the Science of Food and Agriculture, 65, 13–20.

Ørskov, E.R. and McDonald, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural Science, Cambridge, 92, 499–503.

Osuji, P.O., Sibanda, S. and Nsahlai, I.V. 1993. Supplementation of maize stover for Ethiopian Menz sheep: effects of cottonseed, noug (*Guizotia abyssinica*) or sunflower cake with or without maize on the intake, growth, apparent digestibility, nitrogen balance and excretion of purine derivatives. Animal Production, 57, 429–436.

Reed, J.D., Capper, B.S. and Neate, P.J.H., ed. 1988. Plant breeding and the nutritive value of crop residues. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 7–10 December 1987. Addis Ababa, Ethiopia, ILCA.

Reed, J.D., Soller, H. and Woodward, A. 1990. Fodder tree and stover diets for sheep: intake, growth, digestibility and the effects of phenolics on nitrogen utilization. Animal Feed and Science and Technology, 30, 39–50.

Seawright, A.A., Hegarty, M.P., James, L.F. and Keeler, R.F., ed. 1985. Plant toxicology. Proceedings of Australia–USA Poisonous Plants Symposium, Queensland, Department of Primary Industries, Yeerongpilly, Brisbane, Australia.

Siaw, D.E.K.A., Osuji, P.O and Nsahlai, I.V. 1993a. Evaluation of multipurpose tree germplasm: the use of gas production and rumen degradation characteristics. Journal of Agricultural Science, Cambridge, 120, 319–330.

Siaw, D.E.K.A., Kahsay Berhe and Tothill, J.C. 1993b. Screening of two *Sesbania* species for fodder potential and response to phosphorus application on an acid soil in Ethiopia. In: Kategile, J.A. and Adoutan, S.B., ed., Collaborative research on *Sesbania* in East and southern Africa. Proceedings of an AFRNET Workshop held in Nairobi, Kenya, 9–14 September 1991. Nairobi, Kenya, ILCA, 91.

Skerman, P.J., Cameron, D.G. and Riveros, F. 1988. Tropical forage legumes, 2nd ed. Rome, FAO.

Stares, J.E.S., Said, A.N. and Kategile, J.A., ed. 1992. The complementarity of feed resources for animal production in Africa. Proceedings of the joint feed resources networks workshop held in Gaborone, Botswana, 4–8 March 1991. African Feed Resources Network. Addis Ababa, Ethiopia, ILCA.

Sumberg, J.E. and Atta-Krah, A.N. 1988. The potential of alley farming in humid West Africa—a re-evaluation. Agroforestry Systems, 6(2), 163–168.

Tanner, J.C., Reed, J.D. and Owen, E. 1990. The nutritive value of fruits (pods with seeds) from four Acacia spp. compared with extracted noug (*Guizotia abyssinica*) meal as supplements to maize stover for Ethiopian highland sheep. Animal Production, 51, 127–133.

Topark-Ngarm, A. and Gutteridge, R.C. 1990. Fodder productivity of perennial *Sesbania* species. In: Macklin, B. and Evans, D.O., ed., Perennial *Sesbania* species in agroforestry systems. Proceedings of a Workshop in Nairobi, Kenya, March 27–31, 1989. A special publication of the NFTA, 79–88.

Umunna, N.N., Osuji, P.O., Nsahlai, I.V., Khalili, H. and Saleem, M.A. 1994. The effect of supplementing oat hay with either lablab, sesbania, tagasaste or wheat middlings on the voluntary intake, nitrogen utilization and liveweight gain of Ethiopian Menz sheep. Small Ruminant Research, in press.

Varvikko, T., Khalili, H. and Crosse, S. 1992. Supplementation of native grass hay with cowpea (*Vigna unguiculata*) hay, wilted leucaena (*Leucaena leucocephala*) forage, wilted tagasaste (*Chamaecytisus palmensis*) forage or a wheat middling for young Friesian × Zebu (Boran) crossbred steers. Agricultural Science in Finland, 1, 247–253.

Wiegand, R.O. 1991. Tree leaves in the diets of small ruminants. M.Sc Thesis, University of Wisconsin–Madison, USA.

Wilson, A.D. 1977. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. Australian Journal of Agricultural Research, 28, 501–508.

Wilson, A.D. and Harrington, G.N. 1980. Nutritive value of Australian browse plants. In: Le Houerou, H.N., ed., Browse in Africa. Addis Ababa, Ethiopia, ILCA, 291–297.

Woodward, A. and Reed, J.D. 1989. The influence of polyphenolics on the nutritive value of browse: a summary of research conducted at ILCA. Addis Ababa, Ethiopia, ILCA. ILCA Bulletin 35, 2–11.

Agroforestry Plantation Systems: Sustainable Forage and Animal Production in Rubber and Oil Palm Plantations

P.M. Horne*, T. Ismail† and Chong Dai Thai†

Abstract

Integration of animal production with conventionally-spaced oil palm and rubber plantations is restricted by low light levels which result in low forage yields, stocking rates and liveweight gains. While these may be acceptable in some plantation systems, especially with feed supplementation, expansion of integrated animal–plantation production systems will depend on improving the forage resource. Shade-tolerant forages show promise for the moderate shading in young plantations, but are not likely to improve forage quality and availability in mature plantations. Sustainable forage and animal production in conventionally-spaced plantations will depend on staggered replanting to ensure continuity of adequate forage supply in young plantations.

An alternative to this is to eliminate the problem by changing the planting pattern of the trees to allow some areas of the plantation to be permanently set aside for production of forages under little shade. One promising scheme, double hedgerows, is discussed.

THE rapidly growing economies of Southeast Asia have created substantial increases in demand for animal products, especially meat. In recent years, domestic demand for bovine meat in Southeast Asia has consistently outstripped domestic supply. Despite increases in animal numbers (Table 1) imports of bovine fresh meat into Indonesia, Malaysia and Thailand in 1990 totalled 42000 million t compared with only 1300 million t of exports. Given existing animal management practices, Remenyi and McWilliam (1986) estimated that the demand for forage resources in Southeast Asia will double (from 1985 figures) by the year 2000 and meat self-sufficiency will fall from 95% to 62%.

Given the limited land area available for monoculture animal production, plantations (specifically rubber, oil palm and coconut) are the largest areas available for expansion of animal production (especially small ruminants) in Southeast Asia (Shelton et al. 1987; Iniguez and Sanchez 1991; Shelton and Stür 1991; Sivaraj et al. 1993). This paper discusses the prospects of sustainable forage and animal production in rubber and oil palm agroforestry plantation systems (the prospects for coconut plantations are dealt with by Stür, these proceedings).

For the purposes of this paper, agroforestry plantation systems are defined as landuse systems in which plantation crops are grown in association with pastures and animals in a spatial arrangement, a rotation or both, and in which there are both ecological and economic interactions between the tree and pasture/animal components of the system (after Young 1989). The viability of plantation–animal integration in the future will depend on the long-term sustainability of integration, which can be best summarised as incorporating:

- little or no negative effects on growth and yields of plantation crops;
- levels of forage production that can maintain both long-term and economically acceptable levels of animal production; and
- substantial economic benefits of the agroforestry plantation system over the plantation monoculture.

The potential negative effects of animals on growth and yields of plantation crops come from the brows-

* Small Ruminant Collaborative Research Program, Sub Balai Penelitian Ternak, North Sumatra, Indonesia.

† Rubber Research Institute of Malaysia, Experimental Station Sungai Buloh, Selangor, Malaysia.

ing of fronds/leaves, interference with latex-collection cups, and soil compaction. However, it has been generally found that these negative effects can be eliminated by simple management of stocking rates, age of plantations grazed and the type of grazing animal. Sheep, for example, are the best choice of animal for rubber plantations because of ease of management and minimal damage to rubber trees greater than 2 years old. Goats and cattle have been successfully integrated with both young and mature oil palm plantations. There are also some significant positive effects of sound animal management in plantations, including substantial reductions in weeding costs and use of herbicides, more efficient recycling of nutrients and the conversion of otherwise useless plantation forages into meat and other animal products (Devendra 1993). In general, simple management of grazing animals, the net effect of grazing on plantation yields is neutral or even beneficial. Chen et al. (1979) and Chen et al. (1991), for example, found no negative effects of cattle grazing in young oil palm plantations up to 5 years old on fresh fruit bunch yield, so long as stocking rates were kept at or below 2 beasts/ha. At higher stocking rates significant damage to fronds of young trees reduced fresh fruit yields. In later research, Chen (1992) reported 10% higher yields in the first 5 years of palm harvesting when weeds were suppressed by grazing cattle as compared with ungrazed plantations. Jusoff (1988) found significant positive effects of sheep on nutrient cycling and tree girth in a 3-year-old rubber plantation after only 1 year of grazing.

The land areas available for integration of animals with rubber and oil palm plantations are substantial (Table 2). Little information is available on the extent of livestock integration into existing plantations but it is clearly very low. In Malaysia, while a large proportion (44%) of the national sheep population is in rubber and oil palm plantations, this is equal to only 74000 head (1989 figures) (Tajuddin et al. 1991). In Indonesia sheep are not normally found in the plantation areas outside Java (only 7% of the national sheep flock is located in Sumatra which has 54% of the plantation area of Indonesia) (Biro Pusat Statistik 1992). In Thailand, only 18% of the sheep population is found in the southern areas, which account for 61% of the plantation area (mostly rubber) (Vijchulata 1991). The biological potential for animal production in these under-utilised plantation areas is determined largely by the forage production potential, which is in turn dependent on the management characteristics of the existing plantation systems.

Forage Production Potential of Existing Plantation Systems

The productivity of native forages and the changes in botanical composition over time in conventional rubber and oil palm plantations (those with regular planting patterns) are summarised in Table 3. The main problems associated with the forage resource as an oil palm or rubber plantation ages are a rapid and severe decline in productivity and a reduction in the proportion of palatable species. The legume cover-crops in rubber and oil palm plantations (*Pueraria javanica, Centrosema pubescens* and *Calopogonium* spp.) are not very shade tolerant and are rapidly replaced by shade-tolerant native grasses and broadleaved species, especially under grazing. The resulting low forage yields and quality (especially lower digestibility and energy content and higher stem:leaf ratios) in mature plantations generally lead to lower voluntary forage intake, and hence lower energy and protein intake, limiting animal production per head and per hectare (Horne et al. 1993). In conventional rubber plantations, the productivity of native forages will decline from 5–7 t DM/ha/year in 1–2 year old plantations to 1–5 t DM/ha/year in 2–5 year old plantations and <1 tDM/ha/year thereafter.

Despite these problems, most large estates and many smallholdings in Thailand, Malaysia and Indonesia have potential for profitable integrated animal production. Smallholder plantations account for the majority of the area of rubber and oil palm production in Southeast Asia (Table 2) and most of these, being conventional plantations, have adequate forage

Table 1. Livestock numbers in Indonesia, Malaysia and Thailand in 1991.

	Indonesia	Malaysia	Thailand	Total Southeast Asia
	(million head)			
Cattle	10.4 (3.5)[a]	0.7 (1.9)	6.0 (2.6)	34.3 (3.7)
Sheep	5.8 (3.8)	0.2 (15.7)	0.2 (25.6)	6.4 (3.6)
Goats	11.3 (4.0)	0.3 (–0.8)	0.1 (11.7)	15.5 (3.6)

[a] Figures in brackets are average annual growth rates since 1981.

Source: FAO (1992).

resources (as described in Table 3) to support integrated animal production. These include:

- nucleus and plasma estates in Indonesia (approximately 550 000 ha, representing 21% of all smallholder farms) consisting of smallholder estates (oil palm and rubber) developed by government and private estate companies using high-yielding, even-aged trees, regular planting intervals and intensive management (Dereindra et al. 1991). These estates consist of 2 ha of plantation and 0.25–0.5 ha of cropland per smallholder.
- state-sponsored smallholder schemes in Malaysia (FELDA, RISDA, FELCRA) which have resulted in the development of over 250 000 ha of smallholder rubber plantations and over 450 000 ha of oil palm plantations (Yew et al. 1986).
- state-sponsored smallholder schemes in Thailand, where the majority of smallholders use management practices recommended by the larger estates.
- most smallholder oil palm plantations, which are generally indistinguishable from the larger estates in the management practices that will affect animal production.

However, in Indonesia, most of the smallholder rubber area (>2 million ha) is unconventional or 'jungle rubber', consisting of a dense mix of irregularly-spaced and uneven-aged rubber, timber and fruit trees resembling a rainforest, with little existing potential for livestock integration (Gouyon et al. 1993).

Animal Production Potential of Existing Plantation Systems

The animal production potential of existing conventional plantation systems will vary substantially with plantation management practice, age and location (Table 4). Even though low forage yields result in low stocking rates, it can be seen that acceptable levels of production are possible, especially in Indonesia and Thailand where labour costs are relatively low. However, even in Malaysia, where labour costs are high (US$6.00/day for a rubber tapper compared with US$1.20/day in Indonesia), animal integration with plantations can be beneficial simply as a cheaper and safer form of weed control. Animal productivity, especially on the forages of mature plantations, can be improved through supplementation with plantation by-products and waste products, such as palm kernel cake, palm oil mill effluent, *ex-decanter* palm oil solid waste, rubber seed meal and agro-industrial by-products such as molasses, rice bran, cassava meal and fish meal. Energy supplementation of sheep grazing forages in mature rubber plantations appears to be especially beneficial, but may only be economic for weaned lambs and ewes immediately pre-and post-partum (Sanchez and Pond 1991). Supplementation will be essential for improved breeds (such as the hair sheep breeds in Indonesia and Malin × Dorset in

Table 2. **Rubber and oil palm plantation areas and production statistics, Thailand, Indonesia and Malaysia.**

	Thailand	Malaysia	Indonesia
Natural rubber			
Total plantation area, 1992 ('000 ha)	1844	1837	3155
Change in area since 1989 (%)	5.6	–1.0	1.4
Smallholder producers (% of total area)[a]	95	81	83
Latex production, 1992 (% world total)	26.8	21.9	24.9
Oil palm			
Total plantation area, 1992 ('000 ha)	109	2167	1181
Change in area since 1989 (%)	–	21.5	48.8
Smallholder producers (% of total area)[a]	–	54	31
Palm oil production, 1992 (% world total)	2	53	24

[a] Smallholders defined as holdings less than 40 ha.

Sources: Vijchulata (1991); IRSG (1993); Ministry of Primary Industries, Malaysia (1993); Biro Pusat Statistik (1992).

Table 3. Forage production potential of existing plantations sown with cover crops.

	Age (years)		
	1–3	3–5	5–10
Oil palm			
PAR (%)[a]	95–85	85–40	<40
Standing dry matter (t/ha)	3.0	2.2	0.5
Botanical composition (%)[b]			
Legume	28	6	2
Grass	40	58	60
Other palatable species	22	19	13
Unpalatable species	10	17	27
Stocking rate (cattle/ha)	3	2	1
Rubber			
PAR (%)	95–65	65–20	<20
Standing dry matter (t/ha)	1.9	0.4	0.5
Botanical Composition (%)			
Legume	79	37	10
Grass	14	31	37
Other palatable species	2	22	5
Unpalatable species	0	3	44
Stocking rate (lambs/ha)	17–14	14–4	4–2

[a] Photosynthetically active radiation.

[b] Will vary according to site and season.

Sources: Sivaraj et al. (1993b); Chen and Chee (1993); Wilson and Ludlow (1991); Chong et al. (1991a, b); Chen et al. (1979); Chen (1992).

Malaysia) to achieve their reproductive and growth potentials.

Existing oil palm and rubber plantation systems have some inherent management problems for animal production. The reduction of forage yields as a plantation matures and the consequent necessity to reduce stocking rates means that flocks/herds must either be constantly moved to new areas of immature plantation or supplemented with cut-grass and concentrates in the barn. In some systems, such as the nucleus rubber estates of Indonesia, this is feasible. However, for commercial-scale enterprises, the labour costs involved and slow returns on investment make integration of animal production with plantations less attractive to investors. These problems can be partly overcome by improving the forage resource.

Improving the Forage Resource in Existing Plantation Systems

Two possibilities for improving the forage resource of oil palm and rubber plantations are:

- introduction and management of improved forage species; and
- alternative plantation systems to promote long-term, sustainable forage production.

Introduction and management of improved forages

A large number of improved forage species, with the potential to improve the forage resource in large oil palm and rubber estates, have been reviewed by Chen and Ibrahim (1983), Chen and Omar (1984),

Table 4. Animal production potential from native pastures in rubber and oil palm plantations.

	Feeding regime	Performance variable
Mature rubber		
Ram lamb growth		
STT and SC × STT	Free grazing, no supplementation	ADG 45–68 g/hd/day
SC × STT	6–12 animals/ha ± supplement	ADG 80–117 g/hd/day
SC × STT	6–12 animals/ha ± supplement	LWG 175–490 kg/ha/year
SC × STT	Cut forage + concentrate supplement	ADG 78–166 g/hd/day
M × D	Free grazing, no supplementation	ADG 43–95 g/hd/day
M × D	Free grazing + concentrate supplement	ADG 63–106 g/hd/day
Ewe reproductive performance		
STT	Free grazing, no supplementation	0.68–0.92[a]
STT	Free grazing, supplementation at up to 1.4 % BW	0.76–1.13[a]
M × D	Free grazing + PKC supplement 200 g/hd/day	16.2[b]
M	Free grazing + PKC supplement 200 g/hd/day	7.7–14.3[b]
Young oil palm		
Ram lamb growth		
M	Free grazing, no supplementation	ADG 61 g/hd/day
M × D	Free grazing, no supplementation	ADG 95–100 g/hd/day
M × D	10 lambs/ha	LWG 250–350 kg/ha/yr
Cattle		
KK	Free grazing of native pasture + grass/legumes	ADG 260–379 g/hd/day
KK	1–3 hd/ha on native pasture + grass/legumes	LWG 117–284 kg/ha/year
KK	2 hd KK cattle/ha	ADG 234–390 g/day
Goats		
Malaysian local	Free grazing + cut forage	ADG 50 g/hd/day

[a] kg lamb weaned/kg ewe/year.

[b] kg lamb weaned/ewe/year.

STT = Sumatra thin tail; SC × STT=St Correct × STT F_1 crossbreed; M = Malin; M × D = Malin × Dorset Horn crossbreed; KK = Kedah Kelantan breed.

ADG = average daily gain; LWG = liveweight gain; BW = body weight; PKC = palm kernal cake.

Sources: Ranges in the table were compiled from Sanchez (1988); Sanchez (1991); Sanchez and Pond (1991); Chong et al. (1987); Chen et al. (1979); Chen et al. (1991).

Wong et al. (1985a, b), Shelton and Stür (1991) and Sanchez and Ibrahim (1991). The ideal species should have the following properties (Horne et al. 1993):

- persistent and productive under moderate shading and grazing/cutting;
- able to grow well on acid soils;
- rapid establishment to control weeds, especially *Imperata*;
- negligible competition with the plantation crop for water or nutrients;
- only moderate fertilisation needed to provide the nutrients required for plant growth and animal production;
- establishment costs no greater than conventional cover crops; and
- higher yield potential of better quality forage than from the conventional cover crops.

Some species that meet most of these criteria have been sown in experiments to investigate agronomic and animal production potential in large rubber estates (Chong et al. 1994; Horne et al. 1994). These include the grasses *Brachiaria humidicola, Brachiaria brizantha, Paspalum notatum* and *Panicum maximum* and the legumes *Stylosanthes guianensis* and *Arachis pintoi.* It is expected that by using mixtures of these species, forage production in 2-year-old plantations can be increased to around 15 t DM/ha/year with stocking rates of 20–35 DSE/ha. However, it is not expected that any of the improved species will persist under grazing in mature rubber plantations. For this reason, the value of these improved forages for smallholders is limited, except on the large cooperative smallholder schemes such as RISDA in Malaysia. Smallholders have less ability to adjust animal numbers to match forage resources or move flocks around to ensure grazing in young plantations.

Establishment of these improved forages in conventional plantations can be problematic, not only because of the requirements for weed control during establishment, but also because of the inability to graze the forages when the plantation trees are too young. Without grazing, competition from the forages can depress tree growth. One way of overcoming this in rubber plantations is through the use of core-stump or high-budded-stump planting material (Leong et al. 1986). These are grafted seedlings that, instead of being transplanted directly into the field, are raised in nurseries for two years before transplanting. The advantage is that grazing can commence as soon as the forages are ready with no risk of damage to the trees. However, the disadvantages are that the canopy of core-stump plantations closes earlier than that of plantations established with grafted seedlings, and core-stumps entail a greater cost and possible higher risk of failure due to wind damage and poor transplanting success. A possible alternative is to establish conventional cover crops at the time of tree transplanting, followed by spraying of 2 m wide strips after 20 months, which are then established with the improved forages and grazed after 4 months (Tajuddin et al. 1991). This method has yet to be evaluated for efficiency and cost. Given the spatially uneven and rapidly changing light environment in a young plantation, it is also likely that a mixture of species adapted to high and low light conditions will be more successful than a single species pasture.

Persistence and feeding value of improved forages in the moderate shade of young conventional plantations may be better under light but frequent grazing than under heavy or continuous grazing, since regrowth of shaded forages is likely to be more dependent on residual leaf area after grazing than on mobilisation of root carbohydrate reserves. A rapid rotational grazing system would give the best control over this kind of pasture utilisation, but it would require investment in fencing and continual monitoring, which is possibly not justified by the short-term benefits to animal production before the canopy closes. Shepherded grazing, which is common in rubber and oil palm plantations in Indonesia, can be managed to imitate rotational grazing. However, there is a conflict of recommendations between the frequency of grazing for optimising pasture quality and production (3–4 weeks in young plantations and 6–8 weeks in mature plantations) and the frequency of grazing required to adequately control gastrointestinal parasite larvae in the field (3 months or more). The grazing system used will have to be simple and will depend largely on the relative costs and benefits of pasture establishment and maintenance, fencing and sheep parasite control (Horne et al. 1993). Since forage yields from each area of immature plantation decrease rapidly with increasing shade, replanting would ideally be staggered so that there are always areas of better forage within easy walking distance of the flocks/herds.

Alternative plantation management

The inherent problems of forage production in conventional plantations has led to a re-examination of alternative rubber plantation management systems, that allow more light into some areas of the plantation to support sustainable forage production. Similar approaches may also be appropriate for oil palm plantations. The system that has attracted most interest is known as hedgerow plantings. In conventional rubber plantations regular tree spacings result in an even distribution of 400–450 trees/ha with canopy closure after 4–5 years. In hedgerow plantings, the distribution of trees is uneven with rows of trees and wide intervening alleys for permanent crop or forage pro-

Table 5. Comparison of some features of conventional and hedgerow plantation systems.

	Conventional rubber, native forages	Conventional rubber, improved forages	Double hedgerow, improved forages
Initial tree density (per ha)	416–462	416–462	400–420
Forage DM yield (young rubber)[a]	5–7 t/ha/year	12–15 t/ha/year	12–15 t/ha/year
Forage DM yield (mature rubber)[a]	<1 t/ha/year	<1 t/ha/year	8–10 t/ha/year
Regrowth interval (mature rubber)[a]	>6 weeks	>6 weeks	3 weeks
Stocking rate DSE (1–3 years)	14	35–20[a]	40–30[a]
Stocking rate DSE (3–5 years)	14–4	20–4[a]	40–30[a]
Stocking rate DSE (5–10 years)	2–4	2–4	30–20[a]
Stocking rate DSE (>10 years)	2–4	2–4	20–15[a]
LWG (kg/ha/year)	500–50	700–50[a]	1000–900
Savings on weeding costs	15–25%	15–25%[a]	>50%
Estimated net return of sheep ($ million)	62	138–147[b]	114–245[b]

[a] Estimate.

[b] First figure is for grass/legume mix followed by N-fertilised grass mix. Note that these figures are relative indicators only as they are subject to significant variation as latex prices and costs of production change. The figure for double hedgerows includes an estimated 10% reduction in latex yields.

Sources: Wan Mohammed (1977); Tajuddin and Chong (1994a, b); Stür (1991).

duction. Hedgerows were initially investigated in Indonesia in the 1930s for the incorporation of coffee and cacao into rubber plantations and then in Malaysia in the 1950s mainly to try to reduce rubber tapping costs. In Malaysia, research was abandoned because of low yields of latex per hectare resulting from low tree populations but in Indonesia, it was reported that latex yields were equal to, or higher than, those from conventional plantations; an effect attributed to selective thinning of the densely planted trees in the hedgerows.

The main attraction of hedgerow plantation systems for improved forage production is that they create a permanent agroforestry plantation system with potential benefits for both plantation management and sustainable sheep production at reasonable levels of productivity per hectare. The Rubber Research Institute of Malaysia (RRIM) is currently investigating a double hedgerow system that consists of hedges of two rows of trees (planted with a spacing of 2 × 3 m) with a 22 m wide alley between the adjacent hedges (Fig. 1). The potential advantages of this system, as summarised in Table 5, consist mainly of relatively high and sustainable forage and animal production from the predominantly unshaded forages in the alleys, and possibly only minor reductions in latex yield resulting mostly from increased competition between the closely planted trees. The estimated net returns from incorporation of sheep into the different plantation systems compare with net returns from conventional monoculture rubber plantations of $M490–874/ha, at the time of the analysis (Stür 1991).

Double-hedgerow rubber plantation systems could be applied to both large estates and organised smallholders, and RRIM has a total of more than 200 ha of experimental area. Many of the figures in Table 5 are estimates and will remain speculative until the experiments are more advanced. Double hedgerows are an innovative potential solution to the problems of low and variable animal and forage production in rubber plantations. It is hoped that the system will live up to the expectations alluded to in Table 5 and be optimised (better tree spacings and better management) not only for rubber but also for other plantation crops to give a sustainable agroforestry plantation system incorporating benefits for the tree, forage and animal production components.

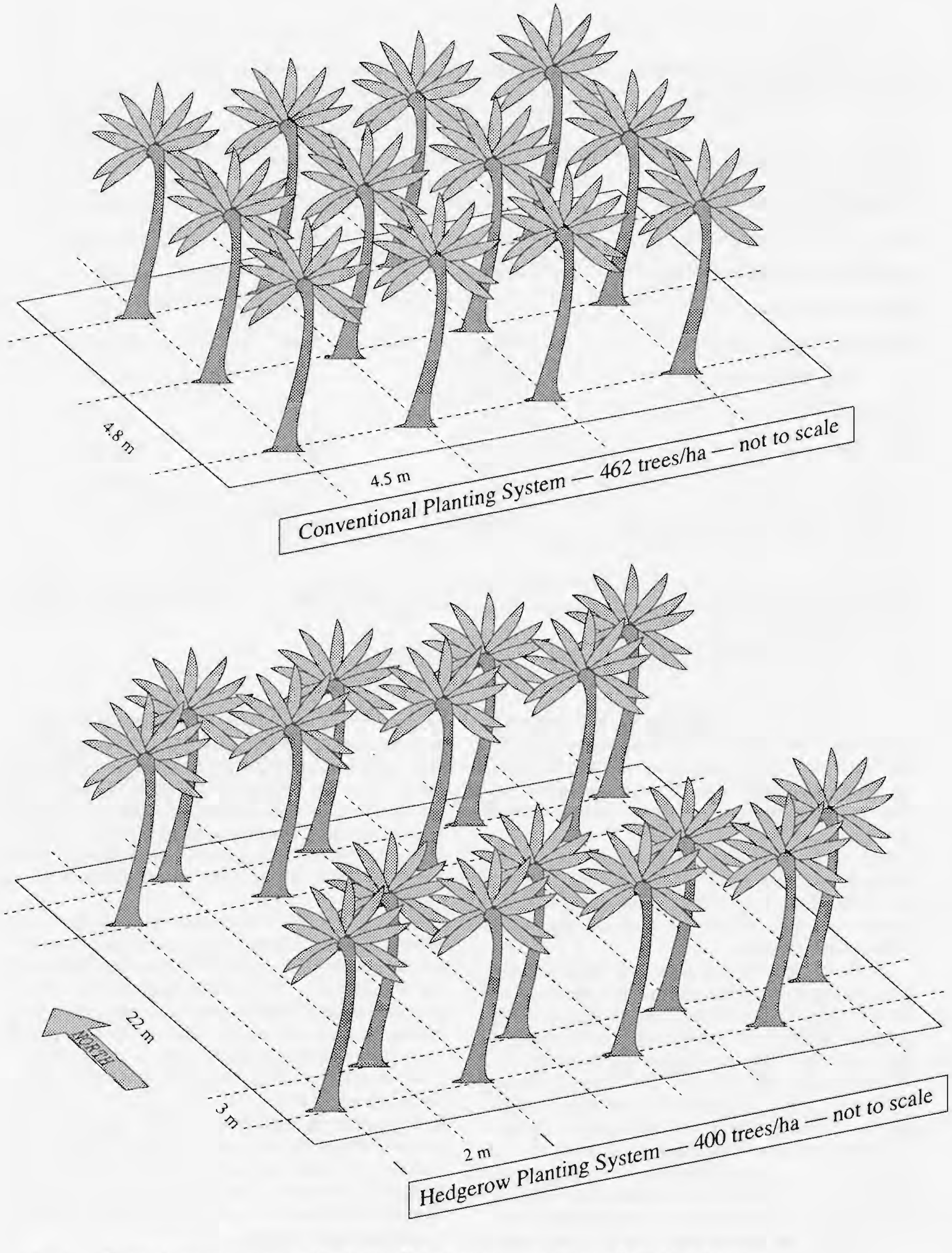

Fig. 1. Comparison of a conventional and a double-hedgerow planting system for rubber plantations.

References

Biro Pusat Statistik. 1992. Statistik Indonesia (Statistical Yearbook of Indonesia). Jakarta, Biro Pusat Statistik.

Chen, C.P. 1992. Integration of cattle under oil palm: feed availability, animal performance and crop yield. In: Ho, Y.W., Vidyadaran, M.K., Abdullah, N., Jainudeen, M.R. and Rani Bahaman, A., ed., Proceedings of the National IRPA (Intensification of Research Priority Areas) Seminar (Agriculture Sector), Kuala Lumpur, 6–11 January 1992. Malaysia, Ministry of Science, Technology and Environment.

Chen, C.P. and Chee, Y.K. 1993. Ecology of forages under rubber and oil palm. In: Sivaraj, S., Agamathu, P. and Mukherjee, T.K., ed., Advances in sustainable small ruminant-tree cropping integrated systems. Proceedings of a workshop held at the University of Malaya, Kuala Lumpur, Malaysia, 30 November–4 December 1992.

Chen, C.P. and Ibrahim, B.J. 1983. Performance of tropical forages under the closed canopy of the oil palm. I. Grasses. MARDI Research Bulletin, 11, 3, 248–263.

Chen, C.P. and Omar, O. 1984. Performance of tropical forages under the closed canopy of the oil palm. I. Legumes. MARDI Research Bulletin, 12, 1, 21–37.

Chen, C.P., Chang, K.C., Ajit Singh Sidhu and Wahab, H. 1979. Pasture and animal production under five-year-old oil palm at Serdang. In: Abraham, P.D., et al., ed., Integration of animals with plantation crops. Proceedings of a seminar held at Pulau Pinang, 13–15 April 1978. Rubber Research Institute of Malaysia.

Chen, C.P., Tajuddin, Z.A., Wan Mohammed, W.E., Tajuddin, I., Ibrahim, C.E. and Moh Salleh, R. 1991. Research and development on integrated system in livestock, forage and tree crops production in Malaysia. In: Ahmad Tajuddin, Z., ed., Proceedings of the International Livestock–Tree Cropping Workshop, 5–9 December 1988, Serdang, Malaysia.

Chong, D.T., Ng, K.F. and Tajuddin, I. 1994. Evaluation of selected forage species in rubber plantation for sheep production. Proceedings of the 7th AAAP conference, Bali, 11–16 July 1994, in press.

Chong, D.T., Tajuddin, I. and Abd. Samat, M.S. 1991a. Stocking rate effect on sheep and forage productivity under rubber in Malaysia. In: Shelton, H.M. and W.W. Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

— 1991b. Productivity of cover crops and natural vegetation under rubber in Malaysia. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Chong, D.T., Tajuddin, I. and Mukherjee, T.K. 1987. Comparative evaluation on the reproductive efficiency of the Dorset Horn crossbreed ewes over the local ewes under rubber. Malaysian Applied Biology, 16, 247–252.

Dereindra, R., Batubara, L., Karo karo, S., Zen, Z. and Arsjad, A. 1991. Prospects for sheep husbandry and socioeconomic constraints in the nucleus estate and smallholder project in Indonesia. In: Iniguez, L.C. and M.D. Sanchez, M.D., ed., Integrated tree cropping and small ruminant production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9–14 September 1990. SR–CRSP, University of California.

Devendra, C. 1993. Relevance of integrated small ruminant–tree crop systems in the development of sustainable agriculture. In: Sivaraj, S., Agamathu, P. and Mukherjee, T.K., ed., Advances in sustainable small ruminant–tree cropping integrated systems. Proceedings of a workshop held at the University of Malaya, Kuala Lumpur, Malaysia, 30 November–4 December 1992.

FAO 1992. Statistical profile of livestock development in Asia/Pacific region (1981–91). Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.

Gouyon, A., De Foresta, H. and Levang, P. 1993. Does 'jungle rubber' deserve its name? An analysis of rubber agroforestry systems in southeast Asia. Agroforestry Systems, 22, 181–206.

Horne, P.M., Gatenby, R.M., Batubara, L.P. and Karo karo, S. 1994. Research priorities for integrated tree-cropping and small ruminant production systems in Indonesia. Paper presented at Seminar Nasional Sains dan Teknologi Peternakan, Ciawi, 25–26 Jahuary 1994, in press.

Horne, P.M., Pond, K.R. and Batubara, L.P. 1993. Strategies to improve forage production in rubber plantations. In: Keane, M., ed., Small ruminant workshop. Proceedings of a workshop held 7–9 September 1993, San Juan, Puerto Rico.

Iniguez, L.C. and Sanchez, M.D., ed. 1991. Integrated tree cropping and small ruminant production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9–14 September 1990. SR–CRSP, University of California.

IRSG 1993. Rubber statistical bulletin. Wembley, U.K., International Rubber Study Group.

Jusoff, K. 1988. Influence of sheep grazing on soil chemical properties and growth of rubber (*Hevea brasiliensis*) in Malaysia. Agroforestry Systems, 7, 115.

Leong, T.T., P'ng, T.C., Gan, L.T., Chew, O.K., Teoh, C.H. and Khairudin, H. 1986. Advanced planting material to effectively reduce immaturity period of *Hevea*. Proceedings of the Rubber Research Institute of Malaysia Rubber Grower's Conference held at Ipoh, 20–22 October 1986, 200–217. RRIM, Malaysia.

Ministry of Primary Industries Malaysia. 1993. Statistics on commodities. Percetakan Nasional Malaysia Berhad, Ibu Pejabat, Malaysia.

Remenyi, J.V. and McWilliam, J.R. 1986. Ruminant production trends in Southeast Asia and the South Pacific and the need for forages. In: Blair, G.J., Ivory, D.A. and Evans, T.R., ed., Forages in Southeast Asian and South Pacific agriculture. Proceedings of an international workshop held at Cisarua, Indonesia, 19–23 August 1985. Canberra, ACIAR.

Sanchez, M.D. 1988. Productivity of sheep under smallholder systems in the humid tropics. In: Vidyadaran, M.K., Saad, Z., Sulaiman, A.W., Azmi, T.I. and M.A. Rajion, M.A., ed., Sheep production in Malaysia. Proceedings of a symposium held at Kuala Lumpur, 15–16 November 1988, Universiti Pertanian Malaysia, 44–61.

— 1991. Supplementation of sheep under rubber in Indonesia. In: Shelton, H.M. and W.W. Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Sanchez, M.D. and Ibrahim, T. 1991. Forage species for rubber plantations in Indonesia. In: Shelton, H.M. and W.W. Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Sanchez, M.D. and Pond, K.R. 1991. Nutrition of sheep that are integrated with rubber production systems. In: Iniguez, L.C. and Sanchez, M.D., ed., Integrated tree cropping and small ruminant production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9–14 September 1990. SR–CRSP, University of California.

Shelton, H.M., Humphreys, L.R. and Batello, C.R. 1987. Pastures in the plantations of Asia and the Pacific: performance and prospect. Tropical Grasslands, 21(4), 159.

Shelton, H.M. and Stür, W.W., ed. 1991. Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Sivaraj, S., Agamathu, P. and Mukherjee, T.K., ed. 1993a. Advances in sustainable small ruminant-tree cropping integrated systems. Proceedings of a workshop held at the University of Malaya, Kuala Lumpur, Malaysia, 30 November–4 December 1992. IDRC Canada.

Sivaraj, S., Agamathu, P. and Tumikin, S. 1993b. Botanical composition and nutritive value of native herbage in an oil palm plantation. In: Sivaraj, S., Agamathu, P. and Mukherjee, T.K., ed., Advances in sustainable small ruminant–tree cropping integrated systems. Proceedings of a workshop held at the University of Malaya, Kuala Lumpur, Malaysia, 30 November–4 December 1992. IDRC, Canada.

Stür, W.W. 1991. Evaluation of alternative sheep grazing options in rubber plantations. In: Integration of forages with plantation crops for sustainable ruminant production. Internal report of ACIAR Project 9113. Canberra, ACIAR.

Tajuddin, I. and Chong, D.T. 1994a. Sheep productivity grazing on naturalised and improved pasture. Proceedings of the 7th AAAP conference, Bali, 11–16 July 1994, in press.

— 1994b. Recent findings on sheep integration under rubber plantations. Paper presented at the seminar 'Peluang Pelaburan Dalam Peternakan Ruminan Komersil', Seremban, 06 May 1994, organised by the Department of Veterinary Services, Malaysia.

Tajuddin, I, Ng, K.F. and Chong, D.T. 1991. The potential and prospects for improving forages under rubber in Malaysia. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Vijchulata, P. 1991. Integrated small ruminant and tree cropping production systems in Thailand. In: Iniguez, L.C. and Sanchez, M.D., ed., Integrated tree cropping and small ruminant production systems. Proceedings of a workshop on research methodologies held at Medan, North Sumatra, Indonesia, 9–14 September 1990, 280–288.

Wan Mohamed, W.E. 1977. Utilisation of ground vegetation in rubber plantation for animal rearing. In: Proceedings of the Rubber Research Institute of Malaysia Planter's Conference, Kuala Lumpur, Malaysia. RRIM, Kuala Lumpur.

Wilson, J.R. and Ludlow, M.M. 1991. The environment and potential growth of herbage under plantations. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR.

Wong, C.C., Rahim, H. and Mohd. Sharudin, M.A. 1985a. Shade tolerance potential of some tropical forages for integration with plantations. I. Grasses. MARDI Research Bulletin, 13, 225–247.

Wong, C.C., Mohd. Sharudin, M.A. and Rahim, H. 1985b. Shade tolerance potential of some tropical forages for integration with plantations. II. Legumes. MARDI Research Bulletin, 13, 249–269.

Yew, F.K., Haridas, G., Daud, N.W., Chan, H.Y. and Raveendran, N. 1986. Land allocation and productivity of Malaysian natural rubber up to the year 2000. In: Rajarao, J.C. and Amin, L.L., ed., Rubber Grower's Conference. Proceedings of a conference held at Ipoh, Malaysia, 20–22 October 1986. RRIM, Malaysia.

Young, A. 1989. Agroforestry for soil conservation. Wallingford, U.K., CAB International, 276 p.

Agroforestry as a Feed Base for Livestock in Semi-arid Regions of Asia

Panjab Singh*

Abstract

Livestock, especially the large and small ruminants, are a valuable resource in the semi-arid Asian region. But their productivity is quite low in most situations. Lack of adequate amounts of quality feed is one of the principal reasons for this.

Incorporation of a leguminous component has potential to improve the quality of existing grasslands. Among such legumes, trees and shrubs assume special importance because of their ability to provide fodder during lean periods, the multiple uses to which they can be put, the ease of their establishment and maintenance, and the possibility of growing them as a component in two-and three-tier systems. Potential species may be incorporated in the farm through various agroforestry options: live fences, alley cropping, plantations on uncropped areas, and agrosilvopasture/silvopastures.

The paper identifies some promising tree/shrub legumes for different agroforestry systems in the region, and discusses management aspects with a view to developing agroforestry as feed for livestock.

RUMINANTS such as buffaloes, cattle, goats and sheep are an extremely important resource in the semi-arid regions of Asia. They contribute meat, milk, fibre and draught power. This in turn is significant to the productivity, stability and sustainability of many developing country farming systems.

Although these livestock are of value to farms, their performance and productivity are generally poor because of limited farm areas, low inputs and low quality and quantity of animal feed. Increasing animal populations and availability of grasslands have created a situation of marked imbalance. Shrubs and trees having fodder value are becoming increasingly important as feeds because of harsh environmental conditions in the region. Also, there exists large areas of marginal lands that cannot support good crop and pasture growth.

Although throughout the developing countries of the region, shrubs and tree fodders are widely available and traditionally used by farmers, these resources are underused in livestock feeding systems. There exists enormous potential to include such resources in conventional farming systems. Such agroforestry systems may be managed for obtaining fodder supplies at regular intervals, especially during lean periods. Thus agroforestry may very well serve as an important feed base for livestock in this region.

In the present paper, an effort is made to explore the possibilities of including shrub and tree legumes in farming systems/grasslands of the region. It also presents an account of management aspects for obtaining regular yields and their effects on livestock productivity.

Livestock Population vs Feed Availability

Livestock has been an essential component of the farming systems of many countries in the region. The region contains the majority of the world's buffaloes and goats. India has the largest bovine population in the world with 191 million cattle and 69 million buffaloes, of which 80–85% are nondescript. The number of milch animals include 50.7 million cattle and 28.3 million buffaloes (Badve 1991). Pakistan has 30.6 million large ruminants (buffaloes and cattle) and 58.5 million small ruminants (sheep and

* Indian Grassland and Fodder Research Institute, Jhansi (UP) 284003, India.

goats). By the year 2000, there will be 19.2 million cattle, 24.8 million buffaloes, 36.6 million sheep and 56.8 million goats (Akram et al. 1990).

In Bangladesh, cattle account for about 90% of the country's animal units. Sri Lanka has 1.8 million cattle, 0.97 million buffaloes, 0.53 million goats and 0.29 million sheep (MIRD 1985). Philippines has 1.6 million cattle, 2.9 million buffaloes and 2.06 million goats (BAI 1988) Between 1975 and 1985 the buffalo population in the region remained almost static. Cattle population showed an annual growth rate of 1.2%. Goat and sheep numbers grew by 1.5% and 1.4% respectively.

Buffaloes and cattle are widely used for draught power. Draughting duties range from a wide variety of ploughing operations to transportation. As the use of tractors involves considerable capital expenditure, the importance of draught animals and their contribution to agriculture are likely to increase in future. Most of the milk and meat supplies come from buffaloes. Goat meat accounts for approximately 63% of the total volume of meat produced in the world. Dairy farming is becoming an important means of promoting social and economic change as well as the pace of rural development.

However, average livestock productivity is low in the region, mainly because of limited farm areas, low input levels, low quality and quantity of feed and low genetic potential of livestock. Contribution towards secondary products, especially milk, due to genetic factors of livestock, is about 25%. According to Remenyi and McWilliam (1986) the low quality and seasonal nature of forage supply, together with low intake by animals and poor digestibility of the forage are the major factors contributing to low productivity of ruminants in the region, especially the arid and semi-arid parts. In such parts the situation becomes quite serious during dry seasons.

The gap between feed requirements and supplies is large. For example, in India, there is a huge annual shortage of concentrates (44%), green fodder (36%) and dry roughage (36%) (Raghvan 1990). In Pakistan, the annual shortage of DCP and TDN is estimated to be around 1.6 and 12.5 million respectively (Akram et al. 1990).

Most of the countries experience a long drought period during which CP content of natural grasses goes below 3%, thus affecting livestock productivity (Evans 1968). The growing period of grasses in the semi-arid regions is short compared to that in the temperate regions. The grasslands are mostly located in marginal and submarginal areas having low fertility. These are invaded by nonpalatable species which dominate with increasing grazing pressure. Thus, there exists a marked imbalance between total ruminant livestock units and available permanent pastures in the region, as compared to other regions of the world.

The Role of Legumes in Improving Feed Quality

Most of the grasses, either native or improved, have comparatively low metabolisable energy values (7.0–11.0 MJ/kg DM) when cut between 2–8 weeks. The digestibility of such grasses lies between 50–60%, which is lower than temperate grasses. The decline in digestibility with age is more rapid in such grasses compared to legumes — a decrease of 0.1–0.2 digestibility units/day.

The legumes have higher metabolising energy values. Their CP and CF is superior to grasses. They retain relatively high digestibility at maturity. Thus, incorporation of legumes in grasslands is particularly valuable for animals in dry seasons. Results from grazing pangola–legume pasture have indicated that liveweight gain of beef cattle was linearly related to legume component in the pasture (Aminah and Chen 1991).

Incorporation of legumes in pasture production systems is better than relying on nitrogenous fertilizers: soil condition improves due to N build up in soil from the accumulation of organic matter; N-fixation through *Rhizobium* synthesis occurs; and increased animal production occurs due to the higher nutritive values of legumes and the shorter digestive passage time in the gut that enhances voluntary uptake.

Higher milk production per cow has been reported in grass–legume mix pastures as compared to nitrogen fertilised grass pasture (Moog 1991).

However, legume viability and persistence are always problematic, especially on acidic soils. There could be several factors that affect the legume component in a pasture. The more important controllable factors are defoliation, grazing management and fertilizers (Aminah and Chen 1991). Presently, little is known about optimum levels of legume components in the grasslands of the region.

Shrub/Tree Legumes

Amongst legumes, shrubs and trees have high potential in this region:

- They have deep root systems and can withstand drought — often serving as the main source of forage during dry seasons.
- Some tree legumes are multipurpose plants and yield fuelwood, timber, pole and even food in addition to fodder.
- These, once established, are easier to maintain in association with grasses as compared to conventional creeping legumes and they can be grown as a component of two or three tier production systems.

Many such legumes are known as a potential source of fodder in the region: genera like *Albizia, Gliricidia, Mimosa, Leucaena, Samanca, Acacia,* *Hardwickia, Dichrostachys, Sesbania, Pithecellobium,* and *Prosopis*. Among these *Leucaena leucocephala* is most well studied. The value of *Gliricidia maculatta* is being increasingly recognised, along with many other species, as a source of fodder.

Agroforestry as a Feed Base

Potential trees and shrubs may be incorporated into the farm through various forms of agroforestry. In this region such incorporation may be achieved in the following four principal ways.

Live fences

Creation of live fences around household and farms may provide not only additional fodder but also fuelwood and food. These may also act as windbreaks and protection against wildlife in specific situations.

Species choice is important. It should have fodder value and should be easily propagated, initially fast-growing, able to withstand frequent lopping and strong winds. Suitable species for the region include *Leucaena leucocephala, Pithecelobium dulce, Gliricidia sepium, Sesbania grandiflora* and *Prosopis juliflora.*

Plantation on uncropped areas

There are opportunities on farmlands and other areas to incorporate trees and shrubs. These include farm boundaries, paddy bunds, forest margins etc. Such plantations may provide not only additional fodder but also timber, fuelwood, vegetables, fruit, and medicines, depending on the species. These also provide shelter for livestock during summer.

Many farmers in the region believe that trees compete with crops for water, light, nutrients and space. Therefore, they are not motivated to plant trees (Sapkota 1988). However, with promotion of trees having multiple benefits including fodder, several fast growing species are being adopted by farmers. Characteristics such as vigorous tap root development, dry season leaf retention, and high digestibility of foliage are preferred. Species like *Acacia aneura, A. nilotica, Cajanus cajan, G. sepium, Albizia lebbek, A. procera, A. amara, L. leucocephala, Prosopis cinerarea, P. juliflora, Pterocarpus marsupium, S. grandiflora, Desmanthus virgatus* have high potential for plantation activity. Of these *L. leucocephala* and *G. sepium* have become popular.

Alley cropping

Alley cropping was originally developed to maintain soil fertility for food crop production. It began to be used for fodder production after leguminous trees were introduced as components.

L. leucocephala and *G. sepium* have potential in alley cropping because of their desirable growth habits and leaf production. Besides these, perennial *Sesbania* spp. can also be used in alley cropping. There is still a need to select tree species based on fodder production ability. During the production period such species should provide fodder in excess of the amount needed for green manure.

Agrosilvoculture/silvopasture

Shrubs or fodder trees may be incorporated in crop fields (agrosilvoculture) or pasture lands (silvopasture). In such systems trees and shrubs may be lopped once or twice a year for fodder and to reduce shading and competition during the growing period of the crops or pastures.

In such systems, fast growing species like *Acacia tortilis, A. nilotica, Albizia lebbek, A. amara, A. procera, Bauhinia* spp., *Dichrostachys cinera, Sesbania* spp., *L. leucocephala, Gliricidia* spp., *Erythrina* spp., *Prosopis* spp. and *Pithecellobium duluce* may be introduced in the region.

Tree Management

Not much information is available with regard to management aspects of trees and shrubs in agroforestry systems. Of several traditional forestry management practices; pollarding, pruning and lopping are of importance in fodder production.

Pollarding management

In this system branches are removed at a height of about 1–3 m above ground level at periodic intervals. This system can be used for managing live fences. Species like *Azadirachta indica, G. sepium, Cassia siamea, Erythina* spp., *L. leucocephala* and *Cajanus cajan* have good pollarding ability.

At Jhansi (India) it was found that a 1-m cutting height in *L. leucocephala* around crop fields (dryland situation) in single hedgerows provided the highest annual forage yield (1.8 t DM/ha) (Pathak and Patil 1982).

In Malaysia *G. sepium* provided a dry matter yield of 2 t/ha/year through pollarding at 1–1.5 m cutting height. In irrigated conditions *L. leucocephala* provided a dry matter yield of 13–22 t/ha/year at 0.5–1.0 m cutting height. *C. cajan* yielded dry matter in the range of 3.7–9.8 t/ha/year with 6–8 week cutting frequencies (Chee 1990).

Pruning management

In this system, small branches and twigs are removed at periodic intervals. It is often required for maintenance of trees, especially in alley cropping and live-fence systems. These clippings may constitute a substantial source of fodder. In *L. leucocephala* and *G sepium* , such clippings may be taken at 6–12 week intervals in alley cropping systems — providing annual average dry matter yields of 7.9–10.7 t/ha respectively. Under irrigation, dry matter yields of up to 20 t/ha/year has been reported from *S. sesban* in 5–6 cuts/year (Topark-Ngaram 1990).

Lopping management

In this system, major branches are removed to obtain fodder, especially during lean periods. The fodder yield is influenced by species, age, moisture level, fertility status of soil, season of lopping, severity of lopping and severity of weather.

In Nepal, Panday (1982) reported fresh fodder yields of 20–400 kg/tree/year in different trees. High yielding trees were *Ficus glaberrima* (400 kg/tree/year) and *F. lacor* (150 kg/tree/year) from a 10-year-old plantation. Trees and shrubs fed to ruminants, and their chemical compositions, have been detailed by Joshi and Singh (1990).

In Jhansi (India), Roy (1989) reported fresh fodder yields of 1–31 kg/tree/year in different leguminous trees. High yielding trees were *Albizia procera* (31 kg/tree/year) and *A. amara* (25 kg/tree/year) from a 6–9-year-old plantation having 440 trees/ha.

In arid zones of India, *Prosopis cinerarea* has been found to produce more fresh fodder (6.3–10.5 kg/tree/year) from annual loppings as compared to loppings done once in four years 95.2–6.9 kg/tree/year). Such trees have remarkable capacity to recover — complete loppings on an annual basis provided more fodder than partial or infrequent loppings (Robinson 1985).

In lopping studies conducted on *L. leucocephala* and *Acacia tortilis* in silvopastoral systems in Jhansi (India) the former gave a peak fodder yield of 1.77 t/ha/year while the latter could provide only 0.62 t/ha/year (Fig. 1) (Singh et al. 1990).

Tree/Shrub Legumes and Livestock Productivity

Generally the CP content (at about 25%) of tree/shrub legumes is higher than that of grasses at similar ages and stages of growth. The fluctuations are less as compared to grasses during the growing process. Apart from N content, these maintain higher S (0.07–0.21%) and Ca (1.3–1.93%) as compared to grasses (0.09–0.15% and 0.17–0.41% respectively). Similarly, values of P in legumes are higher than in grasses. Also, these legumes increase the mineral content of pasture and this has an additive effect on animal nutrition and production.

In the Philippines leucaena is the most popular tree legume. Farmers with small dairies feed their animals on 5–19 kg fresh leaves in combination with fresh grass fodder and obtain 4–7 kg milk/cow/day. The psyillid attack in 1985 badly affected the farmers and forced them to reduce their animal holdings. This suggests that a search for alternative fodder trees for different situations is warranted (Moog 1991).

In Sri Lanka, Liyange and Jayasundera (1988) reported that *Gliricidia* may be used as an animal feed. *Gliricidia* loppings mixed with *Brachiaria milliformis* in a 50:50 ratio and fed to crossbred heifers resulted in an average liveweight gain of 700 g/head/day. These leaves are succulent but not vary palatable to animals when first introduced. However, livestock freely eat them when they become accustomed to them. Similarly, Premaratne (1993) reported that field supplements of *G. sepium*, *Tithonia diversifolia* and *L. leucocephala* have a significant effect on voluntary intake and digestability of rice straw, which in turn resulted in weight gain of sheep (Table 1). Studies in India indicate a significant effect of leucaena supplementation on liveweight gain of calves and goats (Table 2).

In a silvopastoral grazing trial at Jhansi (India) where top feed from *L. leucocephala* and *A. tortilis* was introduced in the diet of animals, growing heifers gained on average 55 g/head/day. Growing lambs gained 44.2 g/head/day (Fig. 2). Breedable Barbari goats gave birth to 19 kids. Performance of lambs and

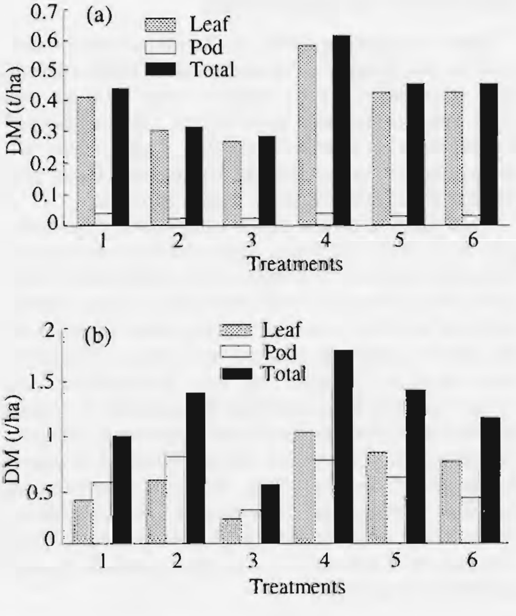

Fig. 1. Lopped fodder yields in different silvopastoral systems at Jhansi: (a) *A. tortilis*; and (b) *L. leucocephala*.. Treatments: 1 = spacing 4 × 3, lopping 25%; 2 = spacing 4 × 4, lopping 25%; 3 = spacing 4 × 6, lopping 25%; 4 = spacing 4 × 3, lopping 50%; 5 = spacing 4 × 4, lopping 50%; 6 = spacing 4 × 6, lopping 50%.

kids under different agroforestry systems showed significant liveweight gains (Table 3). The kids gained from 38 to 46 g/head/day during 9 months. Breedable sheep provided two wool clippings in a year. The average wool production was in the range of 726 g/head/year (Singh et al. 1990).

Future of Agroforestry as a Feed Base in the Region

Milk and meat production in most of the semi-arid Asia region is low. Countries like Korea rapidly expanded milk and meat products, largely based on imported feeds. Although the country has a sizeable trade surplus, it is now paying greater attention to the development of domestic feed resources through agroforestry. In China, the original target of producing 30 million t milk by 2000 had to be revised, mainly because of short feed supplies. Unlike China, Thailand, Indonesia and India have given priority to smallholder dairy farmers in their rural development policies. In India, 'Operation Flood' — the World's largest dairy development project — is based largely on local feeds and indigenous cattle and buffaloes. It is therefore clear that in future agroforestry has enormous potential as a feed base for livestock in this region.

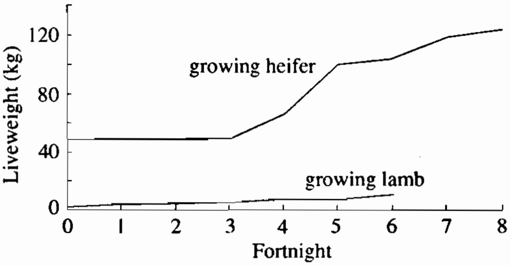

Fig. 2. Patterns of liveweight gain in growing heifers and lambs when fed on silvopastures at Jhansi (India).

Table 1. Effect of fodder supplementation on the DM intake and in vivo digestibility and weight gain in sheep.

Item	Straw	Straw + *G. sepium*	Straw + *T. diversifolia*	Straw + *L. leucocephala*
Feed intake (g/day)				
Total DM	439.8	603.7	633.2	670.0
Straw DM	382.0	380.2	417.6	445.9
DM digestibility (%)	41.7	49.1	51.7	48.2
Weight gain (g/day)	–18.0	268.0	208.0	250.0

Source: Premaratne 1993.

Table 2. Effect of leucaena supplementation on liveweight gains.

	Dry matter intake ($gw^{0.75}kg$)	Dry matter digestibility (%)	Weight gain/loss (g/hd/day)
Calves			
Chaffed mixed with dry grass	114	44	–240
Chaffed mixed with dry grass + 4 kg leucaena leaf/hd/day	114	44	0
Chaffed mixed with dry grass + 2 kg concentrate	140	48	285
Goats			
Dry grass	33	36	–117
Dry grass + 50% leucaena	57	50	13
Dry grass + 75% leucaena	60	47	45

Table 3. Comparative performance of lambs and kids under silvopasture and natural grassland.

Animal species	Silvopasture system			Natural grassland		
	Initial weight (kg/hd)	Final weight (kg/hd)	Weight gain (g/hd/day)	Initial weight (kg/hd)	Final weight (kg/hd)	Weight gain (g/hd/day)
Kids (4–6 months old)	11.8	21.3	40.8	11.8	15.8	17.2
Lamb (4–5 months old)	13.4	27.0	58.4	13.4	21.3	33.9

Future Research Areas

To ensure adequate quality feed supplies in the region, appropriate site–specific fodder–based agroforestry practices are recommended. The following research areas need strengthening:

- An inventory of existing agroforestry practices and their effects on the farmer household economy should be carried out. This research should determine opportunities for, and constraints, for improvement.
- Identification of species that yield high quality fodder in substantial quantity for alley cropping systems.
- Standardisation of various tree management practices in different agroforestry systems in respect of each potential species.
- Investigation of quality aspects of fodder trees and shrubs. The promising species should be ranked in relation to their potential as animal feed and suitability for different agroclimatic zones.

Conclusion

Tree and shrub legumes are valuable components of livestock feeding systems in the region. Increasing population trends indicate that more of the grasslands will be diverted towards crop production and most of the fodder supplies will have to come from marginal areas where crop production is uneconomical. Also, smallholder livestock producers will increase.

In such a situation, tree and shrub legumes will play an even greater role. Livestock research and development programs should focus on using tree and shrub legumes in existing farming systems in a more scientific way. There is also a need for more research on the efficient cultivation, management, and use of, fodder trees and shrubs for livestock production.

References

Akram, M., Hanjra, S.M. Quazi M.A and Bhatti, J.A. 1990 Availability and use of shrubs and tree fodder in Pakistan. In: Devendra, C., ed., Shrubs and tree fodder for farm animals. Ottowa, IDRC, 170–181.

Aminah, A. and Chen, C.P. 1991. Future prospects of fodder and pasture production In: Speedy, A. and Sansoucy, A., ed., Feeding dairy cows in the tropics. Rome, FAO, 127–141.

Badve 1991. Feeding systems and problems in the Indo Gangetic Plains: a case study. In: Speedy, A. and Sansoucy, A., ed., Feeding dairy cows in the tropics. Rome, FAO, 176–183.

BAI 1988. A policy framework for the livestock and poultry sector. Dhaka, Bureau of Statistics, 4–27.

Chee, W.C. 1990. Availability and use of shrub and trees in Malaysia. In: Devendra, C., ed., Shrubs and tree fodder for farm animals. Ottowa, IDRC, 255–265.

Evans, T.R. 1968. Source of nitrogen for beef production in the Wallum. Tropical Grasslands, 2, 192–215.

FAO 1986. FAO Production Year Book No. 40. Rome, FAO, 306 p.

Joshi, N.P. and Singh, S.B. 1990. Availability and use of shrubs and tree fodder in Nepal. In: Devendra, C., ed., Shrubs and tree fodder for farm animals. Ottowa, IDRC, 211–220.

Liyange, L.V.K. and Jayasundera, H.P.S. 1988. *Gliricidia* as a multi–purpose tree for coconut plantations. Coconut Bulletin, 1, 1–4.

MIRD 1985. Sri Lanka livestock statistics. Colombo, Ministry of Rural Development.

Moog, F.A. 1991. Forage and legumes as protein supplements for pasture based systems. In: Speedy, A. and Sansoucy, A., ed., Feeding dairy cows in the tropics. Rome, FAO, 142–148.

Panday, K.K. 1982. Fodder trees and tree fodder in Nepal. Berne, Swiss Development Corporation.

Pathak, P.S. and Patil, B.D. 1982. Leucaena research at IGFRI. In: Proceedings of the Leucaena Workshop, Singapore, Leucaena research in Asia-Pacific Region. Ottowa, IDRC, 83–88.

Premaratne, S. 1993. Role of tree fodders in livestock feeding: MPTS in Sri Lanka—research and development. Proceedings of the Fourth Regional Workshop on Multipurpose Trees, Kendy, Sri Lanka, 12–14 March, 77–79.

Raghvan, G.V. 1990. Availability and use of shrubs and tree fodders in India. In: Devendra, C., ed., Shrubs and tree fodder for farm animals. Ottowa, IDRC, 196–210.

Remenyi, J.V. and McWilliam, J.R. 1986. Ruminant production trends in south east Asia and the south Pacific and the need for forages. In: Blair, G.J., Ivory, D.A. and Evans, T.R., ed., Forages for South Asian and South Pacific agriculture. Canberra, ACIAR, 1–6.

Robinson, P.J. 1985. Trees as fodder crops. In: Caannell, M.G.R. and Jackson, J.E., ed., Trees as crop plants, Huntingdon, U.K., Institute of Terrestial Ecology, 281–300.

Roy, M.M. 1989. Some tropical fodder trees for sustained fodder and for firewood availability during lean periods. Journal of Tropical Forestry, 7, 196–205.

Sapkota, M. 1988. Multipurpose tree species for small farm use in Nepal. In: Sastry, C.B., Withington, D., MacDicken, K.G. and Adas, A.R., ed., MPTS for small farm use. Ottawa, IDRC, 48–52.

Singh P., Pathak, P.S., Upadhyay, V.S. and Gupta, S.K. 1990. Report (VIIIth) of IDRC Silvopasture Operational Research Project. Jhansi, India, IGFRI, 42 p.

Topark-Ngaram, A. 1990. Shrubs and tree fodders in farming systems in Asia. In: C. Devendra, ed., Shrubs and tree fodder for farm animals. IDRC, Ottowa, 12–21.

Cattle Production under Coconuts

W.W. Stür*, S.G. Reynolds† and D.C. Macfarlane§

Abstract

Coconut plantations offer an excellent opportunity for integration of cattle with coconuts. This has become increasingly attractive over the years because of the long-term structural decline in copra prices, while, at the same time, the price for meat has increased.

It is demonstrated that the level of cattle production under coconuts is comparable to that obtained in the open, provided that adapted forages are planted to ensure a sustainable, high quality feed resource.

WORLDWIDE, coconuts occupy between 10 and 11 million ha of agricultural land (Taufikkurahman 1991). The Asia-Pacific region accounts for approximately 90% of the world's area under coconut (Reynolds 1988) with Indonesia and the Philippines being the largest producers of copra and coconut oil in the region.

Successful integration of cattle production with coconut enterprises is based on the premises that cattle are beneficial to the management of coconuts and that the combined income of the two enterprises is greater than that of coconuts alone. In the past, coconut was the main agricultural activity and cattle management was directed towards reducing plantation weeding costs and increasing copra production (largely from a higher recovery of fallen nuts). In recent years the marked fluctuation in copra prices, both monthly and from year to year, and the structural decline in copra prices since 1950 (Fig. 1), has encouraged farmers to diversify and to find a reliable secondary source of income.

Reynolds (1988) demonstrated the importance of a secondary source of income in a case study in Western Samoa (Table 1). The local copra price dropped sharply from US$0.30/kg in early 1975 to US$0.09/kg later in 1975. Based on data for liveweight gain and copra production, the contribution of beef to gross farm income increased from 21 to 41% for a farm with cattle on natural pasture, and from 42 to 71% for a farm with cattle on improved pastures. The farm without cattle suffered a reduction in gross farm income of 70%. Clearly, cattle provided a stabilising influence on farm income, possibly enabling farmers to stockpile coconuts until copra prices recovered. Iniguez and Sanchez (1991) estimated the percentage contribution of the cattle component in a coconut–cattle system in Bali, Indonesia to be 75%. In the Philippines typhoons can completely defoliate coconut trees and cause loss of yield for several years (Deocareza and Diesta 1991).

Cattle production is one avenue for diversification. It is beneficial to coconut production and is increasingly economically attractive both through consistent price increases and price stability. In the Philippines, retail prices for beef have nearly tripled between 1985 and 1992 (Fig. 2). Although increases in actual farmgate prices may have been lower, cattle production compares very favourably with other intercropping options. Similarly, Levine and Soedjana (1991) concluded that the gap between domestic supply and demand for meat is increasing in Indonesia, and this has led to considerable price increases.

Constraints and Benefits

Incompatibility of cattle and coconuts is likely to be caused by unacceptable damage to trees or interference in the management of coconuts.

* CIAT, Tropical Forages Program, Manila, Philippines.

† FAO, Agricultural Operations Division, Rome, Italy.

§ FAO, South Pacific Regional Pasture Improvement Training Project, Department of Livestock, Port Vila, Vanuatu.

Table 1. Effect of fluctuations in copra price on farm gross return (US$/ha/year) in Western Samoa (adapted from Reynolds 1988).

	Gross return (copra) when copra price was		Gross return (beef)	Contribution of beef to gross return when copra price was	
	High[a]	Low		High	Low
	(US$)	(US$)	(US$)	(%)	(%)
Coconuts only[b]	407	122	0	0	0
Coconuts + cattle on natural pastures	407	122	105	21	46
Coconuts + cattle on improved pastures	346[c]	104	249	42	71

[a] High copra price = US$0.30/kg; Low copra price = US$0.09/kg.

[b] Assuming copra production is similar to farm with cattle on natural pasture. In practice it is likely to be lower.

[c] Copra production was initially depressed when improved pasture was established because no fertilizer was applied.

Damage to fronds of young coconuts could be caused by grazing animals and it is usual practice to keep cattle away from young coconuts until fronds are out of reach of the grazing animals. The time required for coconuts to grow beyond the reach of cattle varies, but periods of 3–8 years have been mentioned in the literature (Plucknett 1979). Small ruminants such as sheep have been successfully grazed in 2-year-old coconuts (Simonnet 1990). Damage to stems of coconut is minimal although there are concerns over possible soil compaction (Chen et al. 1978) and increased erosion that may occur when the understorey vegetation is overgrazed.

On the positive side, cattle are important for weed control and this has been the traditional use of cattle in coconut plantations. Light transmission in the commonly used tall coconut varieties decreases from >90% in recently planted coconuts to a minimum of around 40% at an age of 5–10 years, and then increases again with time until the coconuts are due for replanting at age 50–70 years (Fig. 3). Light transmission obviously varies depending on variety (with dwarf or hybrid varieties intercepting more light than the tall varieties), tree spacing and management (Litscher and Whiteman 1982). Much of the area of existing coconut plantations is of tall varieties and often more than 30 years old, therefore light levels are high enough to support an understorey vegetation. Unless it is controlled, this understorey vegetation competes with the trees for water and nutrients.

Grazing can reduce competition from the understorey vegetation by recycling nutrients 'locked up' in the standing biomass. A near doubling of coconut yield was reported by several researchers (Childs and Groom 1964; Ovasuru 1988; Moog and Faylon 1991) when previously ungrazed coconuts were grazed. This was probably only partly related to increased nutrient cycling; the main effect of grazing being related to a higher recovery rate of nuts in short, grazed vegetation. Studies comparing the effect of grazed improved forages with grazed naturally occurring vegetation on coconut yield vary but often the effect is neutral or slightly positive (Reynolds 1988). Moog and Faylon (1991) found that nut yield in

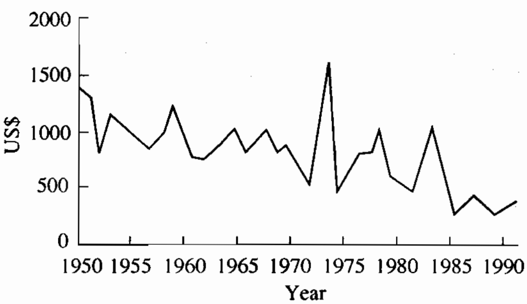

Fig. 1. Copra prices (US$/t, 1990 prices) in Vanuatu, 1950–1992 (Department of Agriculture and Horticulture, Vanuatu 1993).

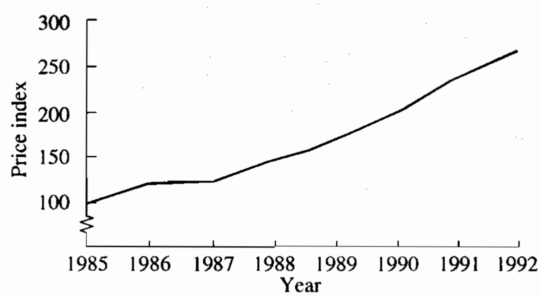

Fig. 2. Retail price index (1985 = 100) for beef, Manila, Philippines 1985–1992 (CRC, various years).

grazed improved pastures (80–100 nuts/tree/year) was higher than for grazed natural pastures (30–50 nuts/tree/year). Negative effects of any understorey vegetation on coconut yield must be expected if rainfall or soil fertility is marginal for coconut growth, although the latter can be ameliorated by sufficient fertilisation. Reynolds (1993) concluded that competition for moisture is likely to occur where annual rainfall is below 1750 mm, particularly if rainfall is not evenly distributed.

As far as animal production is concerned the provision of shade and thus lower heat loads on animals is likely to have a positive effect on animal productivity. The nutritive quality of forages grown in partially shaded environments such as older coconuts is comparable to those grown in full sun (Norton et al. 1991; Kaligis and Mamonto 1991).

Production Systems

Cattle have been used traditionally as 'sweepers' for brush/weed control to assist in the collection of coconuts on larger coconut plantations. However, over the last few decades, with rising demand for animal protein (and rising prices for meat) and falling copra prices, commercial interest in improving ruminant productivity under coconuts has increased in both Asia and the Pacific.

In Asia, smallholder farmers often have one or two cattle which are grazed on whatever feed resources are available in their area. This varies considerably, depending on the available resources and farming system. In many situations cattle are grazed on fallow cropping areas before and after rice or other food crops, and are shifted to plantation areas during the cropping period when there is little available land for cattle. Also smallholders have to maximise use of their limited land resources, and coconuts are usually

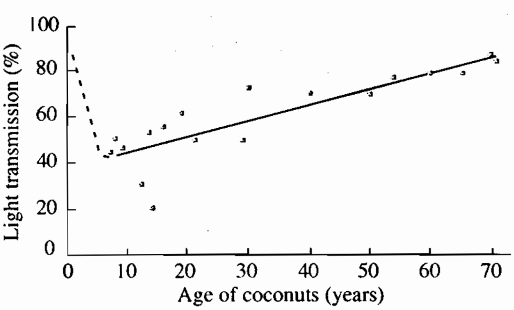

Fig. 3. Relative light transmission (%) profiles with age for coconut plantations (data summarised from Reynolds 1988 and Shelton and Stür 1991).

intercropped with food and other perennial crops such as banana, cloves, pepper and vanilla, particularly in areas with high population density. Despite this intensive land use, there are often small areas under coconuts available for grazing or the growing of forage crops. Cattle are generally tethered in such intensive farming systems and shortfalls in feed are overcome by cutting naturally occurring grasses from communal areas such as roadsides. In these circumstances tree legumes can play a significant role in increasing protein content of the fed material, and thereby animal production. The use of tree legumes grown along field boundaries is particularly widely used in Bali.

In the Pacific, a large proportion of cattle are grazed under coconuts. For example, approximately 85 000 cattle of the national herd of 135 000 head are grazed under coconuts in Vanuatu (Skea et al. 1993). In Fiji, Papua New Guinea (PNG), Western Samoa and Vanuatu, cattle have been used traditionally to control weeds and thus reduce upkeep costs, and to provide an additional income from extra copra and meat. In PNG, Ovasuru (1988) mentions a 70% reduction in upkeep costs and Carrad (1977) refers to substantially reduced labour costs on plantations in the Solomon Islands.

The distinction between 'smallholding' and 'commercial plantation' is blurred with the size of smallholder cattle enterprises varying enormously. For Western Samoa, Tonga, Fiji, Vanuatu and Solomon Islands the average smallholding keeps 10–30 cattle, frequently with up to three households contributing cattle.

In Vanuatu, a survey of 800 smallholdings (Eberhard and Robinson 1993) indicated that 86% of ni-Vanuatu rural households produced coconuts and 47% of rural households kept cattle. The average smallholding with cattle has 2.6 ha open pasture, 7 ha under coconuts and 4.2 ha bush grazing. Tethering of cattle was practiced to some extent by 31% of smallholders, mainly in subsistence rather than in more commercially orientated farms. In areas of high population pressure, cattle under coconuts are rare and intercropping with cocoa, kava and traditional food crops is more common. Macfarlane (1993) reported that for smallholders, gardening is the principal daily activity with commercial cash cropping and livestock production being a secondary activity. The division of responsibilities for activities varies enormously throughout the Pacific between men and women. In Vanuatu, in smallholder enterprises with cattle, there is significant sharing of workloads by men and women, with women participating in cattle/pasture activities in 75% of cases and men spending almost as much time as women in gardening. In other Pacific Melanesian and Polynesian societies, with the exception of dairying in Fiji, women appear to be less involved with large ruminants.

In Vanuatu, coconuts in the commercial plantation sector are largely 60–70 years old but, due to the low copra prices, only 500 ha have been replanted during the last five years. This contrasts with the smallholder sector where approximately 1200 ha were planted annually.

Both cattle breeding and fattening operations are feasible under older coconuts and these may be based on grazing of pastures or cut-and-carry feeding systems.

Cut-and-carry systems extract a considerable amount of nutrients from the forage production area and this is moved to where the animals are fed; particular care is required to return nutrients to the forage area. Neglect to do so may result in loss of coconut yield and cause a sharp decline in forage yield. This is illustrated in Figure 4, where productivity of three grasses, grown under coconuts, was compared at a 2-monthly cutting interval (Rika, pers. comm.). Yield of the tall grass *Panicum maximum* was very high initially but quickly decreased to the level of *Brachiaria decumbens*, a grass of intermediate height, and within 1 year yield declined to a level similar to the yield of the local, prostrate grass *Axonopus compressus*.

Grazing systems are generally found in more extensive coconut production areas such as in North Sulawesi, Indonesia, parts of the Philippines and also in many South Pacific countries. Some tethering is used to control animals but the majority of cattle is herded or animals are allowed to graze freely.

A key factor hampering the development of more commercially oriented cattle production systems under coconuts is the lack of marketing facilities in the more remote coconut plantation areas. The importance of market access for the successful development of a viable cattle industry in the South Pacific was clearly demonstrated by Shelton (1991a).

Animal Production

Grazing systems

The level of animal production reported in grazing trials varies greatly (Table 2). Average daily gains (ADG) vary from 0.12 kg/hd/day to 0.51 kg/hd/day and liveweight gain per hectare varied from 44 kg/ha/year to 744 kg/ha/year. Stocking rates (SR) also varied widely from 1 to 4 cattle/ha (varying sizes) and stocking rate was related negatively to ADG.

The variation in animal production was clearly related to the feed resource available. Liveweight gains were lower on natural vegetation than on improved forages except in the experiments in Solomon Islands where the natural pasture consisted of a very high proportion of legumes. In other cases (Reynolds 1981; Manidool 1984), substantial improvement in LWG was obtained by planting improved pasture. The importance of legumes was clearly indicated in many experiments (Smith and Whiteman 1985; Deocareza and Diesta 1991). Other factors affecting forage growth and therefore animal production were soil fertility and/or fertilizer strategy, and light transmission. In general terms, yield of forages is linearly related to the amount of light available, provided that other factors affecting growth are not limiting (Stür 1991). This means that in a coconut plantation with a light transmission of 50%, the yield of a highly productive grass such as *Panicum maximum* will be approximately 50% of the yield achievable in full sunlight. Animal production is likely to be affected similarly by light transmission. In practice, forages seldom reach their full yield potential because other growth factors such as water and nutrients limit productivity, and light to moderate shading as occurs in older coconut plantations (i.e. >70% light transmission), is unlikely to affect productivity to any great extent. Nevertheless, coconuts take up physical space and this may reduce the available area by as much as 20%. In more shaded situations, animal production will be affected by reduced forage productivity.

This has been shown for Vanuatu (>2500 mm/year rainfall, fertile soils) where stocking rate recommendations for different coconut plantations were almost linearly related to light transmission (Fig. 5).

Shelton (1991b), analysing liveweight data of four long-term stocking rate grazing trials under coconuts (Rika et al. 1981; Watson and Whiteman 1981; Smith and Whiteman 1985; Manidool 1984) by using the stocking rate model of Jones and Sandland (1974), related animal production to pastures. He noted that in three of the four grazing trials persistence of the sown grasses was poor and that the sown grasses tended to be replaced by more grazing-tolerant albeit less productive grasses such as *Axonopus compressus*. Legumes (e.g. *Centrosema pubescens*) were initially more persistent than grasses but eventually also declined while the proportion of weeds such as *Mimosa pudica* and unpalatable weeds increased. He concluded that long-term sustainability of improved pastures under coconuts will depend on the use of grasses tolerant to regular grazing and sufficiently aggressive to keep pastures relatively free of weeds. The challenge then is to find legumes which are compatible with such grasses.

In Vanuatu, the stoloniferous grass *Stenotaphrum secundatum* has proven its ability to suppress weeds better than *Axonopus compressus* or *Paspalum conjugatum* at the same stocking rate (Macfarlane 1993). *Stenotaphrum secundatum* pastures are able to produce high liveweight gains if grown in association with legumes.

Table 2. Cattle production from grazing experiments under coconut.

Country (rainfall)	Pasture	Light transmission (%)	Liveweight gain (kg/ha/ year)	Average daily gain (kg/ha/day)	Stocking rate (cattle/ha)	Reference
Indonesia (1700 mm/year)	Improved	79	288–505	0.22–029	2.7–6.3	Rika et al. 1981
Philippines (>2000 mm/year)	Improved	n.a.	170–315	0.43–0.47	1–2	Moog et al. 1993
	Improved	n.a.	130–158	0.14–0.36	1–3	Deocareza and Diesta 1993
	Improved	n.a.	137–306	0.20–0.37	1–3	
	Natural	n.a.	51	0.14	1	Deocareza and Diesta 1991
	Improved	n.a.	91–146	0.20–0.25	1–2	
Solomon Islands (2900 mm/year)	Natural	60	235–345	0.27–0.40	1.5–3.5	Watson and Whiteman 1981
	Improved	60	227–348	0.27–0.40	1.5–3.5	
	Natural	62	219–332	0.26–0.40	1.5–3.5	Smith and Whiteman 1985
	Improved	62	206–309	0.23–0.35	1.5–3.5	
Thailand (1600 mm/year)	Natural	n.a.	44	0.12	1.0	Manidool 1984
	Improved	n.a.	94–142	0.16–0.26	1.0–2.5	
Vanuatu (>1500 mm/year)	Improved	n.a.	175	0.32	1.5	Macfarlane and Shelton 1986
	Natural	n.a.	250–285	0.26	2.6–3.0	Evans et al. 1992
	Improved	n.a.	550	0.50	3.0	
Western Samoa (2900 mm/year)	Natural	50	148	0.22	1.8	Reynolds 1981
	Improved	50	225–306	0.33–0.47	1.8–2.2	
	Natural	70–84	127	0.14	2.5	
	Improved	70–84	273–396	0.30–0.43	2.5	
	Natural	70–84	401–466	0.27–0.32	4.0	Robinson 1981
	Improved	70–84	421–744	0.29–0.51	4.0	

Source: Adapted from Shelton (1991) and references cited.

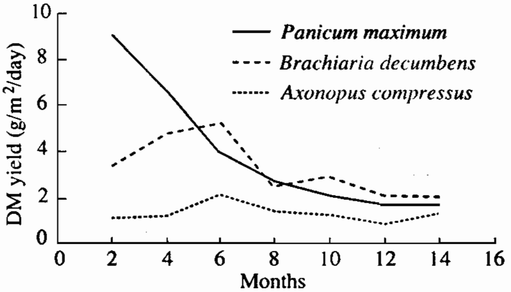

Fig. 4. Yield (g/m^2/day) of grasses grown under coconuts without fertilisation and harvested every 2 months in Bali (I.K. Rika, pers. comm.).

Macfarlane et al. (1994) reported animal production of steers (300 kg liveweight) grazing a *S. secundatum* pasture containing 20% *Desmodium heterophyllum* and *Vigna hosei* under coconuts (65–70% light transmission). Average daily gain was 0.52 kg/hd/day when grazed at 2 steer/ha (380 kg/ha/year) over a 2-year period.

Grazing natural vegetation under coconuts almost invariably results in the invasion of unpalatable weeds and this leads to a rapid decline in animal production. If natural vegetation is grazed heavily, and unpalatable weeds are controlled by slashing, the proportion of grazing tolerant, low yielding grasses such as *Axonopus compressus* will develop, but animal production is generally low.

In Vanuatu, on-farm studies measured liveweight gain of young steers (200–300 kg liveweight) grazing native pasture, consisting largely of *Axonopus compressus, Mimosa pudica* and *Desmodium canum*, under coconuts with a light transmission of 70% (Macfarlane et al. 1994). Daily liveweight gains were 0.30–0.35 kg/hd/day at stocking rates of 1.5–2.0 animals/ha.

Pasture species for the coconut environment have been reviewed by Chen (1991), Reynolds (1993), Shelton et al. (1987), Stür and Shelton (1991), and Wong (1991). Recently, the ACIAR-funded project 'Integration of Forages with Plantation Crops for Sustainable Ruminant Production' identified the following species for grazing under coconuts:

Grasses—*Brachiaria humidicola, Stenotaphrum secundatum, Brachiaria decumbens* grown in mixture with

Legumes—*Arachis pintoi, Arachis repens, Arachis glabrata, Desmodium heterophyllum.*

Species with a similar growth habit which may also be suitable include *Brachiaria dictyoneura, Brachiaria brizantha, Ischaemum aristatum, Stenotaphrum dimidiatum.*

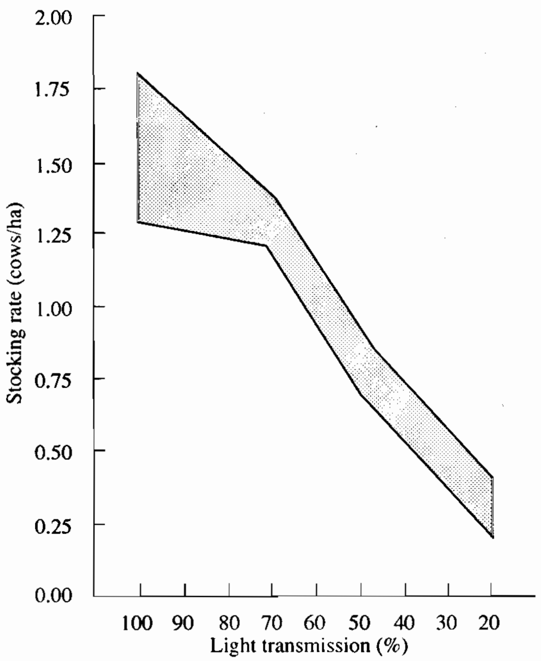

Fig. 5. Recommended stocking rates (cows/ha) for cows with calves under coconuts in Vanuatu (Macfarlane et al. 1994).

Cut-and-carry systems

Small backyard dairy and beef units are common in Bali, Indonesia, Philippines and Thailand, with the grasses *Panicum maximum* and *Pennisetum purpureum* being supplemented with leucaena, gliricidia and various by-products. These are widely used in the tropics because of the small size of holdings and the limited grazing area, the fragmentation of landholdings, a lack of fencing in cropping areas, and the low cost of labour. These grasses are particularly suitable for plantation crops when the trees are young and vulnerable to damage from grazing animals (Sophanodora and Tudsri 1991). Animal production in smallholder cut-and-carry systems is difficult to assess, depending largely on the experience of the operator. Rika et al. (1981) compared the growth rates of 12 Bali cattle leased individually to local farmers and fed cut natural vegetation, banana stem and coconut leaf (a local feeding system) with the growth rates of cattle grazing improved pasture in Bali (Table 3). Average daily gain of cattle in the local feeding system was similar to that at the highest stocking rate in the grazing trial but considerably lower than those obtained at lower stocking rates where animals were able to choose their own diets.

However, a comparison of a cut-and-carry feedlot system, a semi-feedlot system, and free grazing for beef cattle in Johore, Malaysia revealed higher daily liveweight gains for stall-fed animals (Sukri and Dahlan 1986). Trials were carried out with smallholders in West Johore, where coffee was grown as an intercrop under coconuts. Feed rations consisted of coffee by-products (30%), palm kernel cake (37%), urea (2%) and mineral–vitamin premix (1%) and various native forage species (*Paspalum, Axonopus, Ottochloa, Ischaemum* and *Brachiaria*) for grazing. Local × Jersey yearling males were used and the first trial lasted for 178 days. The animals under the feedlot system were confined and fed the feed ration *ad lib.*; the semi-feedlot treatment involved tethering and grazing on the native grasses for 5 hours daily before the animals received the same feed ration *ad lib.* ; the

Table 3. Average daily gain (kg/hd/day) of Bali cattle grazed at various stocking rates (cattle/ha) on improved pasture or fed according to local feeding systems (Rika et al. 1981).

Feeding system	Stocking rate	Average daily gain	
		Period 1	Period 2
	(animals/ha)	(kg/hd/day)	(kg/hd/day)
Local feeding system		0.30	0.17
Cattle grazing	2.7	0.39	0.25
	3.6	0.38	0.25
	4.8	0.37	0.22
	6.3	0.32	0.18

free-grazing animals were tethered to graze the native grasses. Average daily gains of the animals in the feedlot, semi-feedlot and free-grazing systems were 0.48, 0.37 and 0.15 kg respectively. The feedlot and semi-feedlot groups were extended for a further 116 days (trial 2) with average daily gains of 0.60 and 0.38 kg/animal respectively. An economic evaluation demonstrated that gross profit was higher for the feedlot animals than the semi-feedlot or grazing groups (Table 4). It was concluded that feedlot and semi-feedlot systems had great potential for increasing beef production among smallholder farmers and should avoid the major problem of low feed availability (and quality) in dry spells.

In Timor, tethered bulls fatten at an excellent rate of over 1 kg/day on an *ad lib* diet of leucaena leaves plus a metre of banana stem for moisture each day (Harrison 1986). The arrival of psyllids reduced leucaena growth in this system and leucaena has been partly replaced by other tree legumes such as *Sesbania grandiflora*, *Acacia villosa* and *Gliricidia sepium*.

Cattle in cut-and-carry feeding systems depend entirely on the operator for their nutritional requirements. While some farmers are very experienced in selecting forage according to the needs of their animals, often animal production is severely limited in cut-and-carry feeding systems. Reasons for this include: insufficient quantity (no allowance for selection); poor quality (mature, stemmy grasses); and lack of protein.

Advantages and disadvantages of cut-and-carry feeding systems were described in more detail by Whiteman (1980). The problem of declining soil fer-

Table 4. Economic evaluation of different feeding systems (Sukri and Dahlan 1986).

	Trial-1			Trial-2	
	Feedlot	Semi-feedlot	Free grazing	Feedlot	Semi-feedlot
Expenditure					
Average feed ration intake (kg/day)	4.50	2.70	–	5.20	3.00
Cost of ration/kg (M$)	22.10	22.10	–	22.10	22.10
Cost of ration/day (M$)	0.99	0.60	–	1.15	0.66
Revenue					
Average daily gain (kg/day)	0.48	0.37	0.15	0.60	1.33
Revenue from gain (M$/day)	1.68	1.30	0.53	2.10	–
Gross profit					
Gross profit (M$/day)	0.69	0.70	0.53	0.95	0.67
Margin over free grazing (%)	30	32	–	42	–

tility in cut-and-carry feeding systems was addressed earlier.

Conclusions

Coconut plantations offer an excellent opportunity for integration of cattle with coconuts, particularly in the less populated areas where the land under coconuts is not fully utilised.

There are few constraints and, provided that adapted forages are planted to ensure a high quality, sustainable feed resource, cattle production under coconuts will be a profitable and sustainable form of land use.

References

Carrad, B. 1977. Cattle and coconuts: a study of copra estates in the Solomon Islands. Draft report for South Pacific Commission. Canberra, The Australian National University.

Chen, C.P. 1991. Management of forages for animal production under tree crops. In: Iniguez, L.C. and Sanchez, M.D., ed., Workshop on integrated tree cropping and small ruminant production systems, Medan, 9–14 September 1990. Medan, SR–CRSP, 10–23.

Chen, C.P., Chang, K.C., Sidhu, A.S. and Wahab, H. 1978. Pastures and animal production under five-year old oil palm at Serdang. In: Abraham, P.D., Venagopa, L.K., Devendra, C., Hutagalung, R.I. and Rajarao, J.C., ed., Proceedings of a seminar on integration of animals with plantation crops, Penang, 13–15 April 1978. Malaysian Society of Animal Production and Rubber Research Institute of Malaysia, 179–192.

Childs, A.H.B. and Groom, C.G. 1964. Balanced farming with cattle and coconuts. East African Agriculture and Forestry Journal, 29, 206–207.

CRC (Centre for Research and Development) various years. Philippine Agribusiness Factbook and Directory. Centre for Research and Development. A project for the Southeast Asian Science Foundation.

Deocareza, A.G. and Diesta, H.E. 1991. Utilisation of native forages under coconuts in Bicol region. In: De la Viña, A.C., ed., Utilisation of native forages for animal production. Proceedings of Second Meeting of the Regional Working Group on Grazing and Feed Resources of Southeast Asia, 26 February–5 March 1991, University of the Philippines, Los Baños, 155–160.

— 1993. Animal production on improved pasture crops under coconuts. In: Chen, C.P. and Satjipanon, C., ed., Strategies for sustainable forage-based livestock production in Southeast Asia. Proceedings of Third Meeting of Regional Working Group on Grazing and Feed Resources of Southeast Asia, January 31–February 6, 1993, Khon Kaen, Thailand, 189–193.

Department of Agriculture and Horticulture, Vanuatu 1993. The Agricultural Economy 1992: Vanuatu. Port Vila, Economics Division, Department of Agriculture and Horticulture, 18 p.

Eberhard, R. and Robinson, K. 1993. Project impact surveys—methodology and results. In: Evans, T.R., Macfarlane, D.C. and Mullen, B.F., ed., Sustainable beef production from smallholder and plantation farming systems in the South Pacific: proceedings of a workshop, Port Vila and Luganville, Vanuatu, 2–12 August 1993. Brisbane, Australia, AIDAB, 162–176.

Evans, T.R. Macfarlane, D. and Mullen, B. 1992. Sustainable commercial beef production in Vanuatu. Vanuatu Pasture Improvement Project Technical Bulletin No. 4. Department of Agriculture, Livestock and Horticulture, Port Vila, Vanuatu, 68 p.

Harrison, R.E. 1986. The role of improved pastures in commercial production in the tropics and sub-tropics. Tropical Grasslands, 20, 3–17.

Iniguez, L.C. and Sanchez, M.D., ed. 1991. Integrated tree cropping and small ruminant production systems. Proceedings of a workshop, Medan, 9–14 September 1990. Medan, SR–CRSP, 329 p.

Jones, R.J. and Sandland, R.L. 1974. The relation between animal gain and stocking rate. Derivation of the relation from results of grazing trials. Journal of Agricultural Science, Cambridge, 83, 335–342.

Kaligis, D.A. and Mamonto, S. 1991. Intake and digestibility of some forages for shaded environments. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 89–91.

Levine, J. and Soedjana, T.D. 1991. Methodology for establishing selection criteria, marketing, and production aspects for sheep and goats in Indonesia and the ASEAN region. In: Iniguez, L.C. and Sanchez, M.D., ed., Workshop on integrated tree cropping and small ruminant production systems, Medan, 9–14 September 1990. Medan, SR–CRSP.

Litscher, T. and Whiteman, P.C. 1982. Light transmission and pasture composition under smallholder coconut plantations in Malaita, Solomon Islands. Experimental Agriculture, 18, 383–391.

Macfarlane, D.C. 1993. Sustainable animal production from various tropical pasture systems. In: Evans, T.R., Macfarlane, D.C. and Mullen, B.F., ed., Sustainable beef production from smallholder and plantation farming systems in the South Pacific: proceedings of a workshop, Port Vila and Luganville, Vanuatu, 2–12 August 1993. Brisbane, Australia, AIDAB, 180–199.

Macfarlane, D.C. and Shelton, H.M. 1986. Pastures in Vanuatu. Canberra, ACIAR Technical Reports, No. 2, 32 p.

Macfarlane, D.C., Mullen, B.F., Evans, T.R., McDonald, C.K. and Eberhard, R. 1994. Vanuatu Pasture Improvement Project—Final Technical Report. Port Vila, Vanuatu, AIDAB.

Manidool, C. 1984. Pastures under coconut in Thailand. In: Asian pastures: recent advances in pasture research in Southeast Asia. Taiwan, FFTC, No. 52, 204–214.

Moog, F.A., Deocareza, A.G. and Diesta, H.E. 1993. Demonstration trials on improved pastures under coconuts in Bicol region. In: Chen, C.P. and Satjipanon, C., ed., Strategies for sustainable forage-based livestock production in Southeast Asia. Proceedings of Third Meeting of Regional Working Group on Grazing and Feed Resources of Southeast Asia, January 31–February 6, 1993, Khon Kaen, Thailand, 43–48.

Moog, F.A. and Faylon, P.S. 1991. Integrated forage-livestock systems under coconuts in the Philippines. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 144–146.

Norton, B.W., Wilson, J.R., Shelton, H.M. and Hill, K.D. 1991. The effect of shade on forage quality. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 83–88.

Ovasuru, T. 1988. Intercropping and intergrazing in Papua New Guinea. In: Proceedings of a workshop on intercropping in coconut areas, 7–11 September 1988, Colombo, Sri Lanka.

Plucknett, D.L. 1979. Managing pastures and cattle under coconuts. Westview Press, Colorado, USA, Tropical Agriculture Series No. 2.

Reynolds, S.G. 1981. Grazing trials under coconuts in Western Samoa. Tropical Grasslands, 15, 3–10.

Reynolds, S.G. 1988. Pastures and cattle under coconuts. Rome, FAO Plant Production and Protection Paper No 91, 321 p.

Reynolds, S.G. 1993. Pastures and livestock under tree crops: present situation and possible future developments. In: Evans, T.R., Macfarlane, D.C. and Mullen, B.F., ed., Sustainable beef production from smallholder and plantation farming systems in the South Pacific: proceedings of a workshop, Port Vila and Luganville, Vanuatu, 2–12 August 1993. Brisbane, Australia, AIDAB, 77–117.

Rika, I.K., Nitis, I.M. and Humphreys, L.R. 1981. Effects of stocking rate on cattle growth, pasture production and coconut yield in Bali. Tropical Grasslands, 15, 149–157.

Robinson, A.C. 1981. End of assignment report. UNDP/FAO Animal Health and Production Project SAM/76/003.

Shelton, H.M. 1991a. Prospects for improving forage supply in coconut plantations in the South Pacific. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 151–156.

— 1991b. Productivity of cattle under coconuts. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 92–96.

Shelton, H.M., Humphreys, L.R. and Batello, C. 1987. Pastures in the plantations of Asia and the Pacific: performance and prospect. Tropical Grasslands, 21, 159–168.

Shelton, H.M. and Stür, W.W., ed. 1991. Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 162 p.

Simonnet, P. 1990. Sheep flock management in tropical environment under coconut. Oleagineux, 45, 451–455.

Skea, F., Macfarlane, D.C. and Pointing, S. 1993. Beef industry background, structure and economic performance in Vanuatu. In: Evans, T.R., Macfarlane, D.C. and Mullen, B.F., ed., Sustainable beef production from smallholder and plantation farming systems in the South Pacific. Proceedings of a workshop, Port Vila and Luganville, Vanuatu, 2–12 August 1993. Brisbane, Australia, AIDAB, 9–17.

Smith, M.A. and Whiteman, P.C. 1985. Animal production from rotationally grazed natural and sown pastures under coconuts at three stocking rates in the Solomon Islands. Journal Agricultural Science, Cambridge, 104, 173–180.

Sophanodora, P. and Tudsri, S. 1991. Integration of forages for cattle and goats into plantation systems in Thailand. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 147–150.

Stür, W.W. 1991. Screening forage species for shade tolerance—a preliminary report. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 58–63.

Stür, W.W. and Shelton, H.M. 1991. Review of forage resources in plantation crops of Southeast Asia and the Pacific. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 25–31.

Sukri, M.I. and Dahlan, I. 1986. Feedlot and semi-feedlot systems for beef cattle fattening among smallholders. In: Hutagalung, R.I., Hew, V.F., Devendra, C. and Vijchulata, P., ed., Proceedings 8th Annual Conference Malaysian Society of Animal Production, Genting Highlands, 13–14 March 1984, 74–78.

Taufikkurahman, L. 1991. Coconut statistical yearbook 1990. Jakarta, Indonesia, APCC.

Watson, S.E. and Whiteman, P.C. 1981. Animal production from naturalised and sown pastures at three stocking rates under coconuts in the solomon Islands. Journal of Agricultural Science, Cambridge, 97, 669–676.

Whiteman, P.C. 1980. Tropical pasture science. Oxford, Oxford University Press.

Wong, C.C. 1991. Shade tolerance of tropical forages: a review. In: Shelton, H.M. and Stür, W.W., ed., Forages for plantation crops. Proceedings of a workshop, Sanur Beach, Bali, Indonesia, 27–29 June 1990. Canberra, ACIAR Proceedings No. 32, 64–69.

Livestock-based Agroforestry as an Alternative to Swidden Cultivation in Laos

B. Bouahom*

Abstract

It is a government policy objective in Laos to limit and eventually eliminate slash-and-burn shifting cultivation. Attempts by the government in the last decade to limit slash-and-burn cultivation have not been successful, due to a lack of an appropriate working program. This paper considers a livestock-based agroforestry system as an alternative to shifting cultivation.

Smallholders all over the country have good animal husbandry and indigenous knowledge, particularly in some mountainous areas. If this knowledge is used by government to link livestock and agroforestry it will be very useful for a forest rehabilitation compaign. This could help sustain the ecological stability and economical potential of the country.

THE Lao People's Democratic Republic (PDR) is in the process of implementing a government policy to transform agriculture from a production system based on natural or semi-natural processes to a more market-oriented system. Government priorities for the agricultural sector are:

- to achieve food self-sufficiency and have a surplus for domestic markets;
- to limit (and eventually eliminate) slash-and-burn shifting cultivation;
- to increase exports of livestock products (mainly live cattle), tree crops, and other cash crops; and
- the promotion of integrated rural development.

Many tropical countries are attempting to regulate shifting cultivation by various means. In southern China, for instance, the swidden cultivators were encouraged to cultivate by ploughing with buffalo in permanent fields, thus ceasing to clear and burn forest. They were then encouraged to raise the yield per unit of land by introducing intensive cultivation. Unfortunately, the swidden cultivators did not know how to work with ploughs, buffaloes, draught power, or how to seed and transplant rice seedlings, so this attempt to end shifting cultivation failed (Guo 1990).

As in other tropical and semi-tropical countries, the attempts of the Lao Government in the last decade to limit and eventually eliminate slash-and-burn cultivation have not been successful, due to a lack of an appropriate working program. The area under shifting cultivation has not changed for the last decade (Fig. 1).

The Lao Government recognises that after forestry, the livestock and agricultural subsectors, which already play a significant role in the economy, have the greatest potential to increase the living standards of farmers, create employment and earn foreign exchange. This paper focuses on a feasibility study of a livestock-based agroforestry system as an alternative to shifting cultivation.

Livestock Production

There is a great potential to increase livestock production, especially ruminants, in the Lao PDR. Extensive lands throughout the country are well suited to pasture and fodder crops. An estimated 7 to 8 million ha of grazing land is underutilised (comprising natural grasslands, dipterocarp forest and barren lands) of which about 5 to 6 million ha are located in upland areas.

* Livestock Adaptive Research and Extension Division, Department of Livestock and Veterinary Services, Ministry of Agriculture and Forestry, PO Box 811, Vientiane, Laos.

Livestock production is predominantly traditional, and consists of two groups of smallholders who are mainly subsistence farmers (Pravongviengkham et al. 1989). The first group comprises more than 500 thousand smallholders living in lowland areas along the Mekong River. Buffalo and cattle are the most common livestock raised by smallholders—for home consumption, draught and as a 'bank' for sale in times of emergency. The smallholders cultivate an average of about 1.5 ha of paddy field per household and this is their main occupation.

The second group of subsistence farmers comprises 43% of the total population (about 250 thousand families), who live predominantly in the mountainous regions and practice slash-and-burn shifting cultivation. This group of farmers are mostly Lao Theung and Mong. They keep cattle and buffalo for home meat consumption and as a 'savings bank'.

In 1993, there were about 1.2 million buffalo, 1.0 million cattle, 1.5 million pigs, 144 thousand goats/sheep and 9 million poultry (Fig. 2). Smallholders all over the country have good animal husbandry and indigenous knowledge, particularly in some mountainous areas. If this knowledge is used by government to link livestock and agroforestry it will be very useful for a forest rehabilitation compaign. This could help sustain the ecological stability and economical potential of the country.

The livestock industry currently experiences numerous constraints. Primary amongst these is the high incidence of diseases and poor management practices, i.e. poor nutrition and unsustainable production systems. Other important constraints are: insufficient competitive marketing network; insufficient access to credit and inputs; poor technology; and database and staff skill deficiencies (Phonvisay 1994).

Forests

The Lao PDR is rich in forest resources. Forest covered 70% of the country in 1940; 54% remained in 1973, 47% in 1981 and less than 43% or about 11 million ha was estimated to remain in 1993. Based on these figures, we can see that a forest area of approximately 200 to 300 thousand ha was destroyed annually. The rate of current deforestation is an indicator of how fast the country is extinguishing species, destroying watersheds, manipulating microclimates, and affecting carbon and nutrient cycles. If the rates of deforestation continue as steadily as is currently happening, by the year 2000 only 6 million ha will be left, or about 50% of existing forests in 1973. At present, the government is attempting to reforest the country, but it is a slow process.

Causes of deforestation

The main causes of deforestation are permanent conversion of forest to agricultural land; slash-and-burn shifting cultivation; logging; and demand for fuelwood. In Lao PDR the major causes are shifting cultivation and logging.

Shifting cultivation areas in 1993 covered approximately 225 thousand ha, of which more than 90% was in the eight northern mountainous provinces.

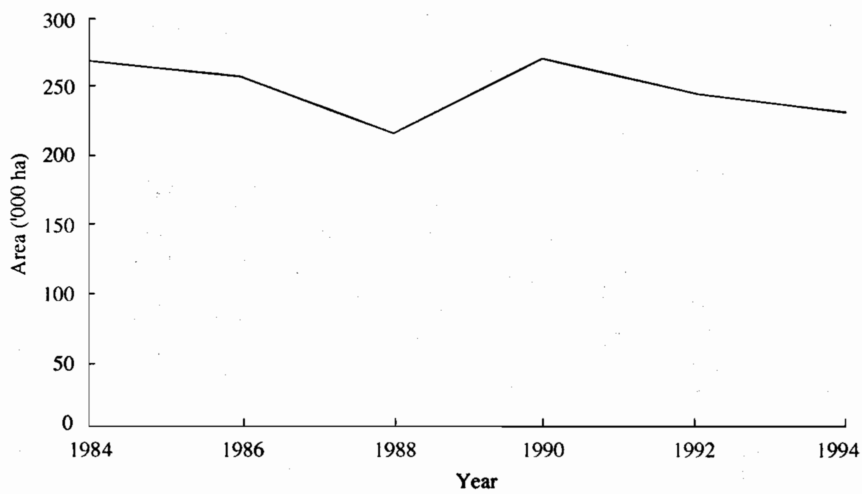

Fig. 1. Area under shifting cultivation, Lao PDR. Source: Lao PDR Statistics Center.

Agroforestry could be one of the appropriate approaches for agroecosystem sustainability, employment creation and increasing the income of the upland people.

Agroforestry

Agroforestry is a collective name for landuse systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions among the different components (Lundgren and Van Gelder 1983: Raitree 1987).

It is very important to get the concept and definition of agroforestry right so that misunderstanding between disciplines of landuse can be avoided. Cooperation is the mother of success in agroforestry, as indeed in any integrated development effort (Kalago 1990).

However, the ultimate goal of agroforestry is to contribute to substainable land systems, maximise total productivity and income while maintaining the productive capacity of the natural resource base (Winterbottom and Hazelword 1987).

Potential of agroforestry

Potential benefits of agroforestry are varied: production of nitrogen, shade, production of wood (especially fuelwood), erosion control, rehabilitation of degraded land, forage/fodder, improvement of rural living standards and employment. Of the benefits listed here, rehabilitation of degraded land, erosion control, forage/fodder for livestock development, and improvement of rural levels and employment are most important for sustainable production in Lao PDR.

Agroforestry models

Researchers in agroforestry use many different approaches and models. But most agroforestry models are in the experimental period or hypothesis stage.

Amongst agroforestry models existing, Agregana (1987) proposed a comprehensive model of small-scale upland agroforestry as an alternative to shifting cultivation in upland areas. He identified four types of agroforestry:

- Agriculture-based agroforestry, where the primary activity involves principles of traditional agriculture.
- Forest-based agroforestry, where the primary activity involves preservation of the forest, and selective exploitation of forest products.
- Fishery-based agroforestry, where the primary activity involves principles of traditional fishery.
- Livestock-based agroforestry, where the primary activity involves raising of ruminant and nonruminant farm animals as the main source of income.

Many researchers are paying more attention to shifting cultivation and have proposed numerous agroforestry models; however, the basic information, research and extension packages for specific areas are still needed.

Livestock-based agroforestry

Livestock-based agroforestry in the upland and highland areas of the Lao PDR could be useful for erosion control, to limit forest degradation, to provide more stable incomes, to create employment, and to eliminate shifting cultivation.

At present, many rural development projects and nongovernment organisations are working in upland

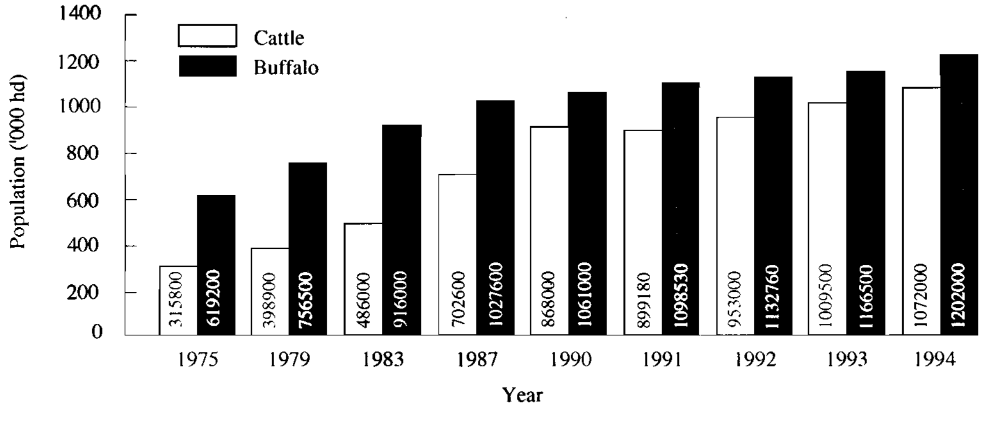

Fig. 2. Livestock population, Lao PDR.

areas, especially in northern provinces of the country, with different approaches and methodologies. For instance, Xiengkhouang Rural Development Project has developed the 'Cattle Bank', where the project purchases cattle for farmers on credit, and provides technical assistance, such as vaccination and animal feed improvement, to the farmers (Archer 1994).

The Lao–IRRI project evaluates different species of grasses, legumes and fodder trees in the upland area of Luangprabang province, with the objectives of improving fallow systems and increasing fodder availability for grazing animals. Various species have shown to be well adapted to the prevailing conditions: lablab (*Lablab purpureus*), pigeon pea (*Cajanus cajan*), *Centrosema pubescens*, *Stylosanthes guianensis*, *Pueraria phasoloides*, *Archis pintoi*, *Leucaena leucephala*, and *Brachiaria brizantha* (Roder et al. 1993; Shelton and Humphreys 1972).

According to our preliminary study, income from livestock was more than 70% of total income per household in the upland area (Bouahom 1994). The upland area has the greatest potential for livestock development because there is more grazing land and lower human and animal population densities. Therefore, the following livestock-based agroforestry system could be an appropriate alternative to swidden cultivation.

The main components of livestock-based agroforestry are livestock, including ruminants and nonruminants, crops, fodder tree legumes, forests and marketing.

As slash-and-burn shifting cultivation is limited, labour will move into other crop production and animal raising. Rice for home consumption can be purchased by selling cash crops and livestock.

Crops produced will be used for consumption, as a feed for animals, and as cash crops. In the system, fodder trees could play a significant role in fodder and fuelwood supply, erosion control, and soil fertility improvement.

Ultimately, the livestock-based agroforestry system will help farmers get more income, increase employment and protect the environment.

Conclusions

It is very difficult to resettle upland people, who practice shifting cultivation, to lowland areas: many countries have tried unsuccesfully to do so. An alternative is to let people remain in their own areas and to use indigenous knowledge to implement appropriate technologies.

Upland farmers practice shifting cultivation because it is necessary for their survival in a difficult environment (Bouahom 1991). An attempt to reduce shifting cultivation should involve detailed step-by-step plans with multidisciplinary approaches, and should be focused on minimising shifting cultivation, and increasing income and employment of the upland farmers. Livestock-based agroforestry as a land management system could be made highly compatible with the upland agroecosystem, rural development, increasing living standards and employment of the people.

References

Agregana, B.C. 1987. Human disturbances in a tropical rainforest: nature, views and approaches. In: Soemarwoto, O. and Rambo, T., ed., Impact of development of human activity systems in Southeast Asia, 31–42.

Archer, J. 1994. Xiengkhouang Highland Development Programme: Cattle Bank Development. In: Proceedings of Conference on Cattle Production Systems, Vientiane, Lao PDR, 64–67.

Bouahom, B. 1991. Agroforestry: possible alternatives to shifting cultivation in the Lao PDR. In: Proceedings of Conference on Recent Research on Sustainable Rural Resource Management in Southeast Asia, Hawaii, 1–14.

— 1994. Cattle production systems: result of the survey. In: Proceedings of Conference on Cattle Production Systems, Vientiane, Lao PDR, 90–99.

Guo, H. 1990. Swidden cultivation and cash crops in Southern Yunnan, China: a case study of agroecosystem sustainability. In: Toward Sustainable Rural Development in Southeast Asia, Hawaii.

Kalago, S.J. 1990. Agroforestry and forest extension in Papua New Guinea. In: Proceedings of a Conference on Community Forestry in the Asia Pacific Region, Bangkok, Thailand, 8–11.

Lundgren, B. and Van Gelder, B. 1983. The potential role of agroforestry in fuelwood production. Stockholm.

Phonvisay, S. 1994. National livestock and fisheries subsector policy, strategy and development programs in Lao PDR. In: Proceedings of Conference on Cattle Production Systems, Vientiane, Lao PDR, 5–7.

Pravongviengkham, P. et al. 1989. The livestock development programme in the Lao PDR. In: Proceedings of the Suan–epai Exploratory Workshop on Lao Agroecosystems, Vientiane, Lao PDR.

Raitree, J.B. 1987. An introduction to agroforestry diagnosis and design. Nairobi, Kenya, ICRAF.

Roder, W. et al. 1993. Research targeting crop–animal systems in the hilly regions of Laos. Paper presented at an International Workshop on Crop–Animal Interactions, Kohn Kaen, Thailand.

Shelton, H.M. and Humphreys, L.R. 1972. Pasture establishment in upland rice crops at Na Peng, Central Laos. Tropical Grasslands, 6, 223–228.

Winterbottom, R. and Hazleword, P.T. 1987. Agroforestry and sustainable development: making the connection. Ambio, 16(2–3), 100–110.

Smallholder Silvopastoralism in Indonesia

J.A. Weinstock*

Abstract

Silvopastoralism is the combination of agroforestry techniques with the raising of livestock. The tree component of this system can provide shade and fodder for the animal component, living fences, erosion control, soil enrichment (in the case of leguminous species), fuelwood, log timber and/or other wood products for home use or for sale, and can combat the intrusion of noxious weeds such as *Imperata cylindrica* grass. Smallholder silvopastoralism has had a long and diverse history in Indonesia that has included the use of a variety of tree species and agroforestry patterns for various purposes. Discussed herein are two examples, one from West Java that is subsistence oriented and one from West Timor that is oriented to the commercial market. The first exemplifies a resilient and ecologically stable polycultural silvopastoral system, while the latter is an example of a rather ecologically unstable monocultural system.

Brief History of Silvopastoralism in Indonesia

AGROFORESTRY has existed in Indonesia for a very long time, with a rich variety of systems presently being found throughout the archipelago. The origins of using tree species in conjunction with livestock rearing in Indonesia is not known, but there is information on the history of the use of some specific tree species. In particular, leguminous tree species have played an important role in Indonesian smallholder livestock rearing during the past half century. Best known among these have been *Leucaena leucocephala, Gliricidia sepium, Gliridicia maculata, Albizia falcataria, Calliandra calothyrusus,* and *Sesbania grandiflora.*

In the 1930s the use of *L. leucocephala* was recommended by missionaries on the island of Flores, and it has been used since the beginning of the 19th century on Javanese and Sumatran plantations as a shade tree for coffee, kapok, vanilla and coconuts (Metzner 1976). More recently the use of improved fast growing varieties of *L. leucocephala* (known locally as *lamtorogung* as opposed to *lamtoro biasa*, or common leucaena) has been tried in rural development programs throughout the country. It has been used for a multitude of purposes including checking erosion, providing green manure to improve soil fertility, as fodder, and as a source of fuelwood. Much of the focus upon leucaena, as opposed to other leguminous species, occurred due to the large amount of attention which leucaena received in the popular media. During the early to mid-1980s countless articles appeared in magazines and newspapers about the tremendous and varied potential of the 'miracle tree' which could provide almost everything to everyone, from fertilizer and food, to fodder and fuelwood. In the mid-1980s a major government campaign was launched throughout Indonesia to plant *lamtorogung*.

For example, in integrated rural development programs for the province of West Java, leucaena was planted with a range of purposes in mind. Most commonly it was used in agricultural projects to control erosion along contours and terraces of sloping rainfed lands, as well as being coppiced for use as a green manure. Often these activities were undertaken in conjunction with livestock projects where the leucaena was coppiced for use as supplemental feed for small ruminants, primarily goats and sheep; planted as living fences (*pagar hidup*) either to keep livestock in or out of fields and home gardens; and the poles used to build livestock pens (*kandang*). An unplanned, although tacitly understood, side benefit has been the use of the leucaena wood by the villagers for their home cooking fires. While *L. leucocephala* seeds had been planted at some of the

* Jalan Guntur 21, Bogor 16151, Indonesia.

Ministry of Agriculture Farmers Extension Stations (*Balai Penyuluhan Pertanian*) beginning in the early 1980s, it was not until 1985 that widespread planting of *l. leucocephala* began. The rapid spread of the use of *l. leucocephala* in West Java occurred due to an edict by the governor that 5 t of *lamtorogung* seed were to be planted in the province during the 1985–86 fiscal year (1 April 1985 to 31 March 1986).

Recognition of the importance of using trees, especially leguminous species, in farming systems might be considered a dramatic move in many parts of the world, but in the case of Indonesia there has been a long history of using a rich diversity of agroforestry systems. Thus the governor's order to undertake a massive campaign of leucaena planting in West Java province was not considered particularly radical or unusual. Farmers in West Java already were familiar with the unimproved variety of leucaena, known as *lamtoro biasa*, as well as various other leguminous tree species.

Calliandra calothyrsus was introduced to Indonesia from Central America in 1936 as a plantation forestry crop and now is widely found growing wild throughout the country (NAS 1980). *Calliandra* is easy to propagate and the coppiced foliage provides good fodder for livestock. The white flowered variety of *Calliandra* is planted at low altitudes, while the red flowered variety is more suited to higher elevations. *Gliricidia sepium* and *Gliricidia maculata* have been used extensively by the Ministry of Forestry in their 'regreening' program. *Gliricidia* spp. has the ability to grow amid the noxious *Imperata cylindrica* grass, locally known as *alang-alang*, and will eventually shade it out. With regard to livestock rearing, this property of *Gliricidia* spp. is valuable since *Imperata* grass has a high silica content which cuts the mouth of livestock grazing on it. Thus the coppiced *Gliricidia* spp. foliage provides a better animal fodder than the *Imperata* grass it displaces.

Other leguminous tree species known and used by livestock smallholders in Indonesia are *Albizia falcataria* and *Sesbania grandiflora* (locally known as *turi*). *Albizia* often can be found in tea estates where it has long been used as a shade tree. Besides using its foliage as livestock fodder, the wood is straight and strong and farmers find it desirable for use as construction poles. *Sesbania grandiflora*, or *turi*, is a leguminous tree native to tropical Asia. It also is widely used for multiple purposes including living fences and for coppicing for animal fodder (NAS 1980).

The government-sponsored push for use of multiple purpose leguminous trees for agroforestry, including silvopastoral systems, in the mid-1980s actually had detrimental effects. Believing the international hype that *L. leucocephala* was a 'miracle tree', government authorities heavily promoted planting of this species. In many parts of Indonesia, as typified by West Java province, the existing smallholder agroecosystems were based upon a mix of leguminous tree species. Thus the promotion of a single species was a step towards the narrow genetic dependency of a monocultural system. The danger of reliance upon a monoculture became all too apparent by early 1986.

The new year opened with a flurry of news on the recently discovered psyllid insects (*Hetropsylla* spp.), commonly known as 'jumping lice', which were infesting stands of leucaena around the world. Originating in the Caribbean, by 1984–85 psyllid infestations appeared in Hawaii and the Philippines. In 1985 psyllid infestation of leucaena was reported in the Bogor Botanical Gardens in West Java. According to reports, the psyllid insects only attack the foliage of leucaena and do not bother other leguminous species. Even certain varieties of *L. leucocephala*, mainly the giant varieties from northwest Mexico, have shown a high resistance to the psyllid (NFTA 1986). In March of 1986 widespread reports of psyllid infestations of leucaena were coming in from around the province of West Java. The spread of the psyllid infestation continued eastward, reaching the islands of Flores and Timor by mid-year. Likewise, the infestation spread to the north, reaching Aceh province in northern-most Sumatra by September where coffee plantations were threatened as their leucaena shade cover disappeared under the defoliation of the psyllids.

The psyllid infestation of *L. leucocephala* had serious repercussions for smallholder livestock rearing in eastern Indonesia, as will be discussed below. Fortunately, the heavy promotion by the government of *L. leucocephala* used as a monoculture had yet to have an impact in West Java. Multi-species silvopastoral systems still predominated among smallholder livestock rearing by the time the psyllid infestation reached western Indonesia, thus tree and foliage loses were minimal. Subsequently, smallholders in West Java had adequate foliage from other leguminous tree species which they could coppice to maintain their animals without any serious impositions (Weinstock n.d.).

Incorporation of tree species cultivation into agricultural systems has taken a rich and diverse variety of forms varying from one Indonesian island to another, and often even from one set of villages to another. Local variations in agroforestry systems frequently have developed in response to a combination of biophysical limitations and socioeconomic imperatives. High levels of precipitation, steep slopes and easily erodible soils in one area may dictate the development of one type of agroforestry system, while in another area seasonal drought may be the predominant factor in development of another type of agroforestry system. Likewise, population pressure, limited access to land, and economic incentives have encouraged development of specific types of market-oriented agroforestry systems in Java, while in some of the outer islands low population densities and the availability of extensive areas of land, but poor market infrastructure, has led to the development of quite different types of agroforestry systems.

Farmers in West Java have favoured intensive silvopastoral systems for goats and sheep in response to limited access to land but good agronomic conditions and well developed market infrastructure. Poor agronomic conditions and restricted market infrastructure, but the availability of extensive land areas, has led to farmers in areas such as on western Timor Island favouring an extensive silvopastoral system for beef cattle. How each of these silvopastoral systems has developed and functions, and how their development has been influenced by socioeconomic factors will be discussed in this paper.

Smallholder Livestock in West Java

High population densities in rural West Java have meant that most farmers have very small land holdings. Thus, what little land to which a farmer does have access, either through ownership or rental, must be devoted to intensive agricultural production for subsistence needs. Wherever adequate water is available and land can be levelled, *sawah* (wet rice) will be cultivated since this is the most productive agricultural system and rice is the dietary staple. Only land without access to irrigation will be used for dryland agriculture. Even in these areas, the need to produce dryland rice, vegetables and fruit for home consumption and local market sales takes precedent. Hence the first choice of livestock for West Java smallholders typically will be chickens, ducks and other fowl which can free-range among horticultural crops and in household yards. These livestock also have the advantage of being inexpensive to purchase and require minimal maintenance.

Ownership of large livestock is desirable among West Java smallholders not only for the economic advantage they provide, but also for sociocultural reasons. Buffalo, cattle, sheep and goat ownership provides the small farmer with social prestige and a living 'bank'. A farmer owning such livestock often commands more respect from fellow villagers than someone who has a nice village house but no animals. The animals owned by such smallholders are not raised in an economically rational manner, such as among commercial livestock operations where the animals are fattened to a specific age or weight size and then sold. More often the small farmer keeps his animals until such time as money is needed to pay for a wedding, to go on the haj, celebrate a religious holiday or fulfill some other sociocultural obligation. But how can a farmer with little or no land to spare for pasture raise large livestock?

While some buffalo and cattle are raised by smallholders in West Java, especially because of their value for use as draught animals, the rearing of very large livestock has been limited. These animals are not only quite expensive and financially beyond the means of most small farmers in West Java, but landholdings are too small to provide even the minimal pasture land and paddock space needed. Thus the large livestock of choice in West Java have been goats, and secondarily tropical varieties of sheep. These animals do not require large paddocks and can survive either with no pasture land or through browsing foliage on the fringes of fields, village lanes and house yards. Traditionally, goats and sheep were allowed to roam free, but this has caused conflicts between neighbours as these animals damage trees, shrubs and crops. Thus increasingly farmers have been building small pens (*kandang*) to hold their animals, or tying their animals to stakes to limit the animal's range. Rearing goats and sheep in pens solves the need for pasture land but creates the problem of providing fodder for the animals. Silvopastoralism, or the use of specific tree species in conjunction with livestock rearing, has provided part of the solution to this problem.

Wild grasses growing along roads, fields and village lanes provide a source of some fodder, and planting of specific varies of grasses, such as *Setaria* or *rumput gajah* (elephant grass), along the borders of fields also provides additional fodder, although this may not be enough. To supplement these grasses, especially during the dry season, West Java farmers have turned to the use of the foliage of leguminous species of trees as a source of fodder. As mentioned above, among the leguminous trees whose foliage has been used by West Java farmers are *C. calothyrsus, G. sepium, G. maculata, S. grandiflora, L.leucocephala,* and *A. falcataria* (Weinstock 1988).

Silvopastoralism in West Timor

The eastern part of Indonesia does not face the intense population pressure encountered in West Java, instead smallholders face a different set of constraints with regard to the rearing of livestock. Taking the West Timor region of Nusa Tenggara Timor (NTT) Province as an example, in most villages there are adequate land areas to graze livestock. Thus, unlike livestock smallholders in West Java, farmers in West Timor are not restricted to goat and sheep rearing but are free to choose large livestock such as cattle and water buffalo. Traditionally Bali cattle, a domesticated variety of the indigenous wild banteng cattle, have been the livestock of choice among West Timor farmers. With assistance from foreign livestock projects over the past two decades there has been a dramatic increase not only in the numbers of

Bali cattle, but also in improved local and imported strains of cattle. Thus, smallholder livestock rearing in West Timor has become more commercial and market-oriented than among smallholders in West Java.

Constraints faced by livestock smallholders in West Timor are poorer agronomic conditions, including seasonal drought as well as poorer soils, and limited market infrastructure. While farmers in West Java may face a dry season of up to 3 months, West Timor has an annual dry season which can last for 8 months. In addition, West Timor has poorer soils than found in most of West Java. Such an agronomic situation provides livestock smallholders in West Timor with a serious challenge.

In addition, transport both within the island and between the island and other islands is difficult and expensive. Taking into account the availability of grazing lands and that the major market for animal products, primarily meat, lies outside of Timor Island (mainly in Java), farmers in West Timor have opted for raising cattle rather than smaller livestock such as goats and sheep. This makes sense not only in terms of economies of scale; (large meat animals instead of small ones), but also since cattle shipped to distant markets suffer less ailments than do goats and sheep. Cattle endure the stress of transport better than goats and sheep, suffer less weight loss and are more likely to arrive alive at the slaughter houses near the market (in this case Surabaya).

To survive the annual dry season, livestock smallholders in West Timor have long relied on silvopastoral techniques. As mentioned earlier, the use of *L.leucocephala* was promoted in NTT Province by missionaries in the 1930s and is now widespread throughout the region. During the early 1980s hybrid varieties of leucaena, or *lamtorogung*, were planted in addition to, or in replacement of, the older varieties of leucaena which are referred to as *lamtoro biasa*. Unlike the multispecies mixes of leguminous trees found in West Java, in West Timor the leucaena plantings and wild propagates almost always have been pure monocultural stands.

During the dry season the stands of leucaena are coppiced to provide fodder for smallholder cattle. In addition, during the dry season banana plants are cut down and the chopped up sections of the trunk feed to the cattle. The purpose of feeding cattle banana trunks is not as a fodder so much as to provide a source of water since the banana trunk contains a high percentage of stored moisture. Thus the combination of banana trunks and coppiced leucaena foliage provide the dry season dietary staple for smallholder livestock in West Timor until the onset of the infestation of psyllid insects (*Hetropsylla* spp.), or 'jumping lice' destroyed this system.

Livestock smallholders in West Java suffered minimally, if at all, when the psyllid infestation struck in 1985–86 since they were less dependent upon the coppiced foliage of leguminous trees and had a variety of species of such trees, most of which were unaffected by this infestation. Conversely, for livestock smallholders in West Timor, this infestation was disastrous. Leucaena trees were quickly defoliated by the psyllids, leaving farmers with little else to feed their cattle. Many smallholders were forced to sell their animals as the psyllid infestation continued through the long annual drought season.

The psyllid infestation ran its course and many leucaena trees in Indonesia recovered from the initial defoliation. This occurred where farmers left the trees alone during the period of infestation. Unfortunately the seriousness of the situation often was compounded in West Timor by livestock smallholders who radically coppiced leucaena trees. This appears to have been done either out of desperation for fodder to feed their animals, or because of the mistaken belief by farmers that such action would eliminate the psyllids. The trees which were radically coppiced or even cut down to ground level usually died.

Conclusions

Livestock smallholders throughout Indonesia have long had experience with agroforestry in a variety of locally developed silvopastoral systems. Each of these systems has developed not only due to the influences of site specific biophysical characteristics, but also due to sociocultural and economic factors. Whether livestock smallholders develop a system which is subsistence oriented or one which has a dominant commercial market orientation also is dictated by these factors. As shown by the West Java example, some Indonesian smallholder silvopastoral systems have been multispecies (polycultural)-based and subsequently have been resilient and ecologically stable. The West Timor example typifies a single species (monocultural)-based silvopastoral system which has been prone to the negative influence, in this case the infestation of 'jumping lice' in the mid-1980s. Countless other variations of silvopastoral systems, which fall between the two extremes described in this paper, can be found in Indonesia.

References

NAS (National Academy of Sciences) 1980. Firewood crops: shrub and tree species for energy production. Washington, D.C., National Academy Press.

NFTA (Nitrogen Fixing Tree Association) 1986. NFT Highlights. NFTA 86–01.

Metzner, J.K. 1976. Lamtoronisasi: an experiment in soil conservation. Bulletin of Indonesian Economic Studies (Sydney), 14, 103–109.

Weinstock, J.A. 1988. Final report of the Provincial Area Development Program — West Java. Jakarta, USAID.

— n.d. Leucaena recovers and a lesson is learned. Unasylva, (date unknown), Rome.

Social Forestry: Concepts and Implications

M. Kaomini*

Abstract

Environmental damage and threats to forest sustainability are a major concern in Indonesia just as they are internationally. The cause of such damage is often the result of a conflict of interest between local people and the national interest. Alternative forest management strategies which benefit forest communities and the nation as a whole therefore must be found. A social forestry program orientated to community welfare and forest preservation is an alternative forest management system. This approach promotes self-reliance, increased community welfare, and awareness of the importance of forest functions and the need for resource conservation.

In recent years, environmental damage has threatened the sustainability of forests. The Indonesian Government therefore has acted to expand forestry activities to safeguard production levels, but at the same time ensure the resource is conserved. These objectives are not easily met since forest resources are under increasing pressure (Nasendi 1989). The problem may be caused by:

- forest encroachments such as illegal wood gathering, unrestrained livestock grazing, illegal land occupancy (Nasendi 1989);
- an increasing commercial orientation within the forest community regarding forest products (Nasendi 1989); and
- the extensive clearing by shifting cultivators, over exploitation by concessioniares, and forest fires (Wangsadidjaja and Ismanto 1991).

Besides these direct factors, indirect factors are contributing to the problem:

- an expanding population has increased demand for forest land and forest products; and
- levels of awareness concerning the need for conservation and protection of the environment are low.

* Asia Pacific Agroforestry Network, Bogor 16004, Indonesia.

Government regulations are now in place to prevent misuse of the forest but these regulations are difficult to enforce, and commonly conflicts of interests arise between and among local people, the forestry sector, and other development sectors. It means the conventional forest management system has apparently failed to cope with the problem satisfactorily (Wangsadidjaja and Ismanto 1991; Kartasubrata et al. 1993).

In order to improve the forest management, alternative management strategies are required. These alternatives need to have benefits to local people and the nation as a whole. Several factors need to be considered in order for any development program to succeed:

- a decrease in conflicts between resource users and authorities protecting natural resources (Royal Forest Department 1989);
- support for local organisations living near important resources so that they may participate in the management and administration of those resources and hence play a part in protecting the environment (Royal Forest Department 1989); and
- a change in the role of department officials from policing to organising and providing technical and custodial assistance (Wangsadidjaja and Ismanto 1991).

Therefore a social forestry program which improves management practices is a new approach being tried in many countries such as Latin America, Africa, and Asia.

Characteristics of Social Forestry Programs

According to Nasendi (1989), 'Social forestry is a participatory activity which involves the forest community in forest land and resource management, and aims to increase local prosperity and increase and diversify forest utilisation, without causing environmental degradation'.

There are other definitions for social forestry, but all of them have similar characteristics (Arihadi 1992; Kartasubrata et al. 1993; Nasendi 1989; Wangsadidjaja and Ismanto 1991). Some of these are:

- orientation to the community's welfare and forest preservation;
- a focus on the high degree of interdependence between the forest communities and the forest;
- providing individual communities or community organisations with responsibility for the management of the forest in their area;
- strategies to transform the relationship between forest communities and forest managers from an adversarial one to a partnership (*mitra sejajar*); and
- a bottom-up development approach where the potential, self-confidence, and ability of the community to organise and develop themselves according to their own priorities are central goals.

Objectives of Social Forestry Programs

According to Hoe (1993), Kartasubrata et al.(1993), Peluso (1992), Perum Perhutani (1992) and Nasendi (1989), the objectives of a social forestry program are:

- to attract the participation of millions of farmer households to the protection of existing natural forests and to be participators in environmental conservation in a nationwide schedule of regreening denuded hillsides;
- to develop the capability, skill and participation of the community to use forest production and to manage the land in an efficient way whether these communities are in forest land areas or not;
- to preserve forest, land, and water in order to gain an equitable distribution of income in the community, and to achieve sustainable economic growth;
- to improve relations between forestry field workers and forest farmers through equal partnership, bottom-up, and top-down communication; and
- to create diverse, sustainable forests, free of disturbance, at the same time as improving the living conditions of local people, particularly those below the poverty line.

Types of Social Forestry

There are several types of social forestry depending on the nature of land ownership, management, and the enterprise objective (Nasendi 1989).

Participatory forestry

The forest area is managed by the government or professional foresters, and the community participates primarily as labourers. This type of activity is more suited to densely populated areas with limited land availability, such as Java. An example is Perum Perhutani's forest village program (*Pembangunan Masyarakat Desa Hutan*, PMDH).

Village forestry

Forest land is managed by the people through existing social institutions (traditional, religious, cooperative and community organisations). This type of management is more suited to the areas outside Java, with lower population densities. An example is the *Dusun Hutan* (village forest) in Irian Jaya.

Community forestry

An example of this type of management is the people's forest (*hutan rakyat*). The forest is managed by landowners, and could be developed in densely or sparsely populated regions.

Farmer forestry

Management is handled by more formal community groups such as small-scale industrial cooperatives.

Tree farming

This type of management stresses intercropping of trees and food crops. The trees are planted on private land to produce for personal use, or for sale as handicraft wood, firewood etc.

Scope of Activities

In order to achieve its goals, the social forestry program covers several activities:

- establishment and development of a forest farmers' group (*Kelompok Tani Hutan*, KTH);
- extension, through leadership and example;
- planting trees, vegetation (reforestation);
- preserving the forest;
- managing, using and distributing forest production;
- managing and marketing forest production; and

- creating inventories of forest resources, resource potential, community forest, and integrated farming activities, and mapping resources.

In the social forestry system, local people are invited to participate in the decision-making process concerning such things as the species to be planted, method of planting, design of the plantation and nature of rotations.

These activities differ depending on whether the area is outside or inside forest land (Nasendi 1989). In the forest area the aim is to apply the participatory management model to intensify agroforestry activities and to increase capital and technological inputs. In privately owned forest, activities concentrate on the introduction and expansion of rational cultivation techniques to increase land productivity as well as the quality of the environment. Forestry officials function primarily as an information resource.

In Indonesia, there are differences in field-level implementation in Java and in the Outer Islands, from both a technical and nontechnical point of view. The outer island program requires planning, organisation and development of a working system to encourage involvement and support of agencies outside the forestry apparatus (Nasendi 1989).

Organisation

The organisation of social forestry differs from place to place, depending on the type of social forestry involved. Since a social forestry program involves the forest community the organisation needs to be cross sectoral involving government and nongovernment agencies and the local farmers.

People involved in the program are organised into groups of forest farmers (*Kelompok Tani Hutan*, KTH), headed by a chief. The presence of the institutions are to facilitate the needs of KTH.

The technical field staff, and the social forestry community organisers (*Penyuluh lapangan Perhutanan Social,* PLPS) are the spearhead of the social forestry program at the local level. The PLPS are functional facilitators and motivators who provide extension, guidance and coordination to the forest farmer groups. They act as catalysts to motivate the participation of local farmers in the program.

References

Arihadi, Y. 1992. Social forestry in Java: a compromise that is working. Forests, Trees and People, Newsletter No. 20.

Hoe, H. 1993. Social forestry programme of Vietnam. In: Workshop on agroforestry and social forestry for rehabilitation of degraded lands. Bogor, Indonesia, SEAMEO–BIOTROP, 9.

Kartasubrata, J., Sumito, S. and Suharjito, D. 1993. Rehabilitation of degraded forestlands through social forestry in Java. In: Workshop on agroforestry and social forestry for rehabilitation of degraded lands. Bogor, Indonesia, SEAMEO–BIOTROP, 1–3.

Nasendi, B.D.1989. Final Report Social Forestry Program Phase I 1986–88. Ministry of Forestry Republic of Indonesia in cooperation with The Ford Foundation, 67 p.

Peluso, N.L. 1992. Rich Forest, Poor People. Resource control and resistance in Java. University of California Press, 321 p.

Perum Perhutani 1992. Implementation of social forestry program in Java. The cooperation between: Perum Perhutani–Ford Foundation, 15 p.

Royal Forest Department. 1989. Final report Thailand upland social forestry pilot project, phase 1, 62 p.

Wangsadidjaja, S. and Ismanto, A.D. 1991. The legal case for social forestry in production forests in Indonesia. In: Fox, J., Lynch, O., Zimsky, M. and Moore, E., ed., Voices from the field. Fourth Annual Social Forestry Writing Workshop, The East West Environment and Policy Institute, Honolulu, Hawaii, 94–112.

ACIAR Proceedings Series
Recent Titles

No. 37 Breeding technologies for tropical acacias. Proceedings of a workshop held in Tawau, Sabah, Malaysia, 1-4 July 1991. L.T. Carron and K.M. Aken (ed.), 132 p, 1992.

No. 38 Forages on red soils in China: proceedings of a workshop, Lengshuitan, Hunan Province, People's Republic of China, 22-25 April 1991. P.M. Home, D.A. McLeod and J.M. Scott (ed.), 141 p., 1992.

No. 39 Newcastle disease in village chickens: control with thermostable oral vaccines: proceedings of an international workshop held in Kuala Lumpur, Malaysia, 6-10 October 1991. P.D. Spradbrow (ed.), 181 p, 1992.

No. 40 Peanut improvement: a case study in Indonesia. Proceedings of an ACIAR/AARD/QDPI collaborative review meeting held at Malang, East Java, Indonesia, 19-23 August 1991. G.C. Wright and K.C. Middleton (ed.), 108 p. 1992.

No. 41 A search for strategies for sustainable dryland cropping in semi-arid eastern Kenya: proceedings of a symposium held in Nairobi, Kenya, 10-11 December 1990. M.E. Probert (ed.), 138 p., 1992.

No. 42 Productive use of saline land. Proceedings of a workshop, Perth, Western Australia, 10-14 May 1991. Neil Davidson and Richard Galloway (ed.), 123 p, 1993.

No. 43 Pasteurellosis in production animals. An international workshop at Bali, Indonesia, 10-13 August 1992. B.E. Spencer, R.B. Johnson, D. Hoffmann and L. Lehane (ed.), 256 p, 1993.

No. 44 Bovine ephemeral fever and related rhabdoviruses. Proceedings of the 1st international symposium, Beijing, PRC, 25-27 August 1992. T.D. St George, M.F. Uren, P.L. Young and D. Hoffmann (ed.), 141 p, 1993.

No. 45 Bacterial wilt. Proceedings of an international conference held at Kaohsiung, Taiwan, 28-31 October 1992. G.L. Hartman and A.C. Hayward (ed.), 381 p, 1993.

No. 46 Draught animal power in the Asian-Australasian region. Proceedings of a workshop held in conjunction with 6th Asian-Australasian AAAP Societies, Bangkok, Thailand. W.J. Pryor (ed.), 135 p, 1993.

No. 47 Biology and mariculture of giant clams. Proceedings of a workshop held in conjunction with 7th international Coral Reef Symposium, 21-26 June 1992, Guam, USA. William K. Fitt (ed.), 154p., 1993.

No. 48 Australian tree species research in China: proceedings of an international workshop held at Zhangzhou, Fujian Provence, PRC, 2–5 November 1992. A.G. Brown (ed.), 226 p., 1994.

No. 49 Sandalwood in the Pacific region: proceedings of a symposium held on 2 June 1991 at the XVII Pacific Science Congress, Honolulu, Hawaii, F.H. McKinnell (ed.) 43 p., 1994.

No. 50 Postharvest handling of tropical fruits: proceedings of an international conference held at Chiang Mai, Thailand 19–23 July 1993. B.R. Champ, E. Highley and G.I. Johnson (ed.), 500 p., 1994.

No. 51 Diagnosis and epidemiology of foot-and-mouth disease in Southeast Asia: proceedings of an international workshop, Lampang, Thailand, September 6–9, 1993. J.W. Copland, L.J. Gleeson and Chanpen Chamnanpood (ed.) 209 p., 1994.

No. 52 Tuna baitfish in Fiji and Solomon Islands: proceedings of a workshop, Suva, Fiji, August 17–18, 1993. S.J.M. Blaber, D.A. Milton and N.J.F. Rawlinson (ed.) 129 p., 1994.

No. 53 Coconut improvement in the South Pacific: proceedings of a workshop in Taveuni, Fiji, November 10–12 1993, M.A. Foale and P.W. Lynch (ed.) 82 p.

No. 54 Soil fertility and climatic constraints in dryland agriculture, E.T. Craswell and J.R. Simpson (ed.). In press.