SILVIPASTORAL SYSTEMS IN TROPICAL CONTEXT

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ABSTRACT

The smallholder farmers in the tropics apart from growing agriculture crops as the main production, also practise traditional silvipastoral systems by growing shrubs and trees and keeping livestock as sideline. In humid and sub-humid wet tropics the emphasis is on the production of trees for timber and energy, while in the semi-arid and arid dry tropics the emphasis is on the production of shrub and tree fodders and livestock. With the increasing knowledge of the adaptability of shrubs and trees to shading, heat and water stresses, production and nutritive values of the shrub and tree fodders and response of the livestock, new and non-traditional silvipastoral systems have been developed to suit the humid and sub- humid wet tropics and semi-arid and arid dry tropics. Intercropping, alley cropping, taungya, sorjan, intensive feed garden, fodder bank, homeplot, sloping agriculture land technology, savannah and three strata forage systems are some of the potential sustainable silvipastoral systems. In view of their potential in helping to meet the increasing demand for timber, energy, livestock products and environmental conservation, the development of silvipastoral systems must be properly planned and evaluated. Success will be achieved, if a more holistic approach is adopted and research support is provided to put the new technologies of the silvipastoral system into practice.

KEYWORDS

Wet and dry tropics, shade tolerance, drought resistance, plantation tree, fodder shrub and tree, livestock, three strata forage system, taungya system.

INTRODUCTION

The tropical zone is located between 23.5° South latitude and 23.5° North latitude, occupies 47% of the world area, and is spread through North Australia, South and Southeast Asia, Central Africa, the Carribean, Central America, South America and the Pacific regions. The climate ranges from wet zone, with 5000 mm annual rainfall distributed during the 9 months wet season and 3 months dry season, to dry zone, with 100 mm annual rainfall distributed during the 4 months wet season and 8 months dry season, with air temperature ranging from 11 - 35°C and relative humidity ranging from 62 - 84% (Isahak, 1994). Such climatic zone patterns classify the tropical area into humid and sub-humid wet tropics and semi-arid and arid dry tropics with average annual rainfall ranging from 2500 - 5000 mm, 1500 - 2500 mm, 600 - 1000 mm and 100 - 500 mm, respectively. Monsoonal rain and thunderstorm falling in Southeast Asia and sand storms that blow in Asia and Africa have special significance on the ecology of the wet and dry tropics.

In Asia and Pacific regions, which contain 69% of the world's agricultural population but only 28% of the world agricultural land, the per capita availability of agricultural land is only 0.27 ha as compared to 1.64 ha in the rest of the world (Mellink et al., 1991).

Despite family planning and birth control programs, the increase in population in tropical countries increases the needs for food for humans, feed for animals, fuel wood for cooking and timber for building and construction. In many cases, such high demand is causing over exploitation of the land through over-grazing, over-defoliation of the fodder shrubs and trees, indiscriminate lopping of the timber trees and continous cropping which consequently reduces the land productivity and increases the land degradability. In many such tropical countries the arable land frontier has already been reached, so that means and ways of meeting the needs of the increasing population must be found. A silvipastoral system is one of the alternatives.

In the broadest sense, agroforestry is defined as any land use which includes both trees and agricultural production on the same piece of land (Mellink et al., 1991). Based on the commodity involved, agroforestry can be classified into silvipasture that includes grass, ground legume and livestock in the shrub and tree integration (Ghani and Awang, 1989). When the crop residue, fodder shrub, fodder tree and animal become important such agroforestry variant is defined as animal agroforestry (Torres, 1983). On the other hand, when fodder shrub, fodder tree and livestock become dominant, such variant is defined as animal silviculture. This development is largely contributing to meet the growing demand for food of plant and animal origin and subsequently is enhancing the socio-economic condition of the rural population and maintaining, if not increasing, sustainability of land utilisation.

In the 17th International Grassland Congress, the silvipastoral system has been discussed in terms of pasture as a secondary component in the tree-pasture system (Chen, 1993) and trees and shrubs as a secondary component of pasture (Atta-Krah, 1993). This paper describes the reality, potential and strategy of silvipastoral system in the humid and sub-humid wet tropics and in the semi-arid and arid dry tropics.

REALITY AND POTENTIAL

Development. The agroforestry system which has existed in the tropics for 100 years and has evolved through years of trial and error, has been successful not only as a way of increasing the timber, energy and food production, but also contributing to the conservation of the environment.

Depending on the dominant and specific production of its components, agroforestry can be specifed into many variants (Fig. 1). When emphasis is on timber and energy production, the agroforestry is specified as a silvicultural system and when a food crop is integrated, the silvicultural system is developed into an agrisilvicultural system. When fodder shrubs and trees, forage and livestock are integrated, the silvicultural system is developed into a silvipastoral system and when agrisilvicultural system, silvipastoral system and crop residue are integrated, such integration is developed into agrisilvipastoral system.

In the humid tropics where the dense ever-green crown canopy of the forest trees slows down the growth of the shrub and grass layers, silviculture for timber production is more common; while in the sub-humid tropics where deciduous trees and plantation trees allow sunlight penetration for growth and production of the first and second layers, silviculture and agrisilviculture are more common. In the semi-arid tropics, where water is limiting, particularly during the dry season, agrisilviculture is less common while silvipasture is more common. In the arid tropic where water and sun stresses are limiting, silvipasture is most common.

The transition leading to dominancy of either the silvicultural system, pastoral system or silvipastoral system depend on the ecological and socio-economic conditions in the wet and dry tropics. During the land reform implementation in Indonesia in 1963 for example, many forests were deforested into intensive smallholder farming systems and many grassland were converted into semi-intensive smallholder farming systems, thus increasing the planting of fodder shrubs and trees for livestock feed.

Humid and sub-humid tropics. In traditional smallholder farming area in the wet tropic, food crop is the main production, while livestock is the sideline activity. Shrubs are grown on the bund of the field and on the fallow land for soil stabilization and along the terrace of sloping land for erosion control. During the wet season livestock are fed grass and crop residue, while during the dry season livestock are fed shrub and tree fodders as a supplement, or as a sole diet when no more grass is available. In the irrigated smallholder farming system in Bali Indonesia, for example, there were 26 fodder shrubs and 31 fodder trees that grow around the bund of a 1 ha field; whereas in the rainfed smallholder farming system there were 104 fodder shrubs and 304 fodder trees (Nitis, 1986). Because of the better price of the industrial crops (e.g. vanilla, clove and coffee) than the food crops (e.g. corn, cassava and soybean), many intensive smallholders shift from annual crops to perennial crops. In this area, many more shrubs and trees are grown to support this system.

During the dry season smallholder farmers and landless livestock holders go to the forest to get shrub and tree fodders and firewood, which is against the policy of the forestry department. However, the plantation crop owner or workers occasionally loped the shrub and trees used as shade, so that the fodder supply in this farming system is more sporadic than continuous.

Semi-arid and arid tropics. The low rainfall and high evaporation in the dry tropics, resulted in the formation of savannah with scattered shrubs and trees for browsing of the ruminant. During the short period of low rainfall, ruminants rely on the natural grass, while during the long dry season ruminants depend on the shrubs and trees for their fodder supply. When the green foliage of the shrub and trees are no longer available, ruminants consume the dry fallen leaves, fruit pods and seeds for maintaining their lives.

In this harsh environmental condition, goats survive better than sheep and sheep in turn survive better than cattle. Cattle lost body weight, sheep maintained body weight, while goats gained in live weight when they browsed on the fodder shrubs and trees (Sarson and Salmon, 1978).

Shade tolerant *vs.* drought resistant characteristics. In the literature review, Chaves and Pereira (1992) have shown that shade and drought induce in different ways the morphological, phenological, anatomical and physiological modifications in trees and understory crops in the agroforestry system. In acclimating plants the most important mechanism is partial closure of the stomata, slow down of foliage growth and changes in carbon allocation pattern modifying the root/shoot surface ratio. During the dry period when stomata are closed for most of the day, the interaction of high light intensity and high tissue temperature with water deficit may result in a decrease in photosynthetic capacity due to enhancement of photoinhibition. The same may occur in shade adapted understory plants if suddenly exposed to high temperature and high incident irradiance under drought deciduous tree canopies. The acclimation to shade is shown by low root/shoot ratio, large leaves, high area/biomass quotient and succeptibility to photoinhibition; while the acclimation to drought is characterised by small leaves that improve stomatal control over transpiration, paraheliotropic movement and increased reflectance of leaves, stomata that are highly sensitive to soil water deficit or low humidity in the air and low area/biomass quotient.

In an agroforestry environment, competition for water is important, since any water saved by one plant will be used by the others (Chaves and Pereira, 1992). In trees stomata may be closed at higher water potential than in herbaceous plants, which may combine intensive water use with a high degree of tolerance to dehydration.

The survival of plants under drought conditions is partly due to maintenances of full photosynthetic capacity by the younger leaves of the canopy which are the least affected by drought, thus allowing a rapid recovery of the plant after dehydration (Chaves and Pereira, 1992). Furthermore, apart from the reduction in carbon assimilation at canopy level and carbon uptake at the leaf level of water deficit, growth of the plant is also inhibited by decreasing foliage areas and by shedding of the lower leaves of the canopy.

CLASSIFICATION

Using the agroforestry criteria described by Nair (1985), the silvipastoral system can be classified according to its structure, arrangement, function, ecological and socio economic criteria. Such classification, it is expected, could give better understanding in identifying the potential, constraint and strategy of implementation of the silvipastoral system in the wet and dry tropics.

System based on the structure and nature of the component. The integration can consist of either forest tree, plantation tree, or fodder shrubs and trees and forage with livestock. The forest trees can consist of ever-green or deciduous trees. The plantation tree can consist of estate crops (such as rubber, coconut, kapok) and horticulture crops (such as orange, mango). The fodder shrubs can consist of shrub legumes (such as gliricidia and leucaena), non-shrub legumes (such as hibiscus, zizinhus) and the fodder trees can consist of tree legumes (such as albizia and erythrina) and non-tree legumes (such as lannea and ficus). The livestock can consist of cattle, buffalo, sheep, goat, deer, horse, poultry, swine or other herbivores.

System based on the arrangement of the component. Shrubs and trees can be planted as a hedgerow, as a fence around the farm boundary, as a cluster either in single or mixed stands, as an alley crop between the agriculture crops, or as guardrow along the terrace of the slopping land. The livestock can be integrated either in confinement on a cut and carry system, and/or on tethered grazing on the short fallow land or on free grazing on the range land.

System based on the function of the component. As a production function, forest and plantation trees can produce timber, energy and fruits; fodder shrubs and trees can produce fodder, while livestock can produce meat, milk and work. As a protective function shrubs, trees and livestock can increase soil fertility through root nodule bacteria, green manure and livestock manure. Shrubs and trees can reduce soil erosion and water run-off and provide shade for crops, animals and men.

System based on the ecological condition. Shrubs, trees and livestock are suitable for humid and sub-humid wet tropics or suitable for arid and semi-arid dry tropics. In terms of topography, shrubs, trees and livestock are suitable for low land, high land and hilly land areas.

System based on the socio-economic criteria. Shrubs, trees and livestock can be integrated either in the smallholder, intermediate or commercial system. Depending on the scale of production, management and technological input, the output can be used for household, domestic and/or export commodities.

TREE-SHRUB-ANIMAL INTERACTIONS

Interactions between genetic (e.g. growth and reproductive potentials) and environmental (e.g. wet and dry tropics) factors could result into associative, synergetic and symbiotic interrelationships leading to a positive impact on the components of the silvipastoral system.

Benefit to the forest and plantation trees. Increase in wood production is due to increased soil moisture through less water evaporation and less water run-off and the ability of different tree species to optimize increse absorption of nutrients from the soil. For example wood production of acacia, pectophorum and eucalyptus forest trees intercropped with agricultural crop was 3.9 - 4.1 times higher than those grown in a monoculture (Petmak, 1991).

The increase in the growth and production of the plantation tree is due to the improvement of soil fertility through increased N supply by the root nodules, increased humus content from the plant litters and less competition for nutrients. For example, the growth and leaf N content of immature rubber increased by intercropping with leguminous creeper (Watson et al., 1964); the yield of palm oil fruit bunches increased with cattle grazing that removed the excessive weeds (Cheng, 1991) and the coconut yield on improved pasture was 56% higher than that under native pasture (Rika et al., 1981).

Benefit to forage, fodder shrubs and trees. Apparently light limitation under a heavy shade of tree canopy in the wet tropic induces the use of increased N supply to promote growth and N deposition in the grass tissues. For example, the crude protein (CP) content of signal grass under 81% shade was 26% higher than those under full sunlight (Halim, 1992). In the dry tropic, however, the high response of the grass is due to higher soil moisture due to the shade and litter of the trees. For example, in the Sahel dry tropic of West Africa, productivity of pennisetum grass under acacia trees was two times higher, the grass dried out 3 - 6 weeks later and the photosynthetic efficiency was 4 times higher than those in the open (Bille, 1978). In semi-arid Queensland, Australia, the yield of cenchrus grass under mature eucalyptus tree was higher than that from the inter tree area (Christie, 1975).

The extent of benefit to the fodder shrubs will depend on their association with different species of grass, ground legume and fodder trees. For example, in dryland farming areas in Bali, Indonesia, the fodder yield of gliricidia in association with cenchrus grass, was 6% higher, while CP content was 11% lower than gliricidia cultivated in association with panicum grass (Lana et al., 1992). Fodder yield, CP, NDF and ADF contents of gliricidia in association with graham stylo, were 9, 3, 6 and 13% higher respectively than the gliricidia in association with verano stylo. Furthermore, gliricidia in association with ficus tree had fodder yield, NDF and ADF contents that were 14, 5 and 11% higher respectively than the gliricidia in association with lannea tree. Similarly, the extent of benefit gained by fodder tree depend on their association with different species of grass, ground legume and fodder shrubs.

Benefit to animal. The benefit gained by livestock supplemented with shrub and/or tree fodders is due to more variety, quantity and quality of forage and fodder integrated in the silvipastoral system. For example, goat grazing under mixed deciduous forest produced 25% bigger litter size, 12% heavier birth weight and 9% heavier weaning weight than goats kept in confinement (Cheva-Isarakul, 1996). In the semi-arid region of Central Queensland Australia, during the dry season, steers grazing a cenchrus/leucaena mixture gained 2.2 times more live weight than those grazing grass only (Wildin, 1993). Furthermore, 2 year old cattle grazing heteropogon grass supplemented with leucaena fodder gained 94% more live weight and had better carcass quality than those grazing grass only (Foster and Blight, 1993). In cut and carry system, sheep fed pennisetum grass supplemented with sesbania fodder gained 2.7 - 5.0 times more live weight than those fed grass only (Mathius and Van Eys, 1983). Reynolds (1995) review of the pasture-dairy-coconut system indicated that milk production increased 22 - 62% by supplementing pennisetum or brachiaria grass with leucaena fodder. During the 3 month dry season in Bali, Indonesia, goats fed solely green gliricidia fodder or ficus fodder gained live weight, while the goats fed solely dried natural grass lost live weight (Sukanten et al.,1996). In dry land farming areas in Bali, Indonesia, Bali steers stall-fed a mixture of improved grass, ground legume, shrub legume and tree fodders in the three strata forage system gained 13% more live weight, efficiency of feed utilization was 24% better and there was 67% less infection with parasites than the cattle fed native grass only (Nitis et al., 1995). For the Bali heifer the oestrus interval was 31% faster, oestrus frequency incresed by 6%, duration of oestrus was 4% longer and silent heat was 20% less (Pemayun et al., 1996).

Benefit from consuming shrub and tree fodders depend on the species of the animal. For example, the higher voluntary intake of goat than sheep fed different ratios of grass to leucaena, with the highest intake from diet containing 75% leucaena and 25% grass (Devendra, 1984), is probably due to the bigger stomach capacity and higher preference to browse of the goat than the sheep. Cattle lost weight and sheep maintained weight when browse forage with nutritional value ranging from 0.25 - 0.46 feed units (Fu/kg DM); while goat gained weight even when the browse forage nutritional value is only 0.19 FU (Sarson and Salmon, 1978).

Benefit to the animal utilizing the shrub and trees is affected by management practices and environmental factors. For example, “Kampung” hens roaming the land planted with a food crop, improved grass-legume, fodder shrubs and trees in the three strata forage system produced 56% heavier egg weight, 58% bigger egg size, 37% more eggs and had a 33% longer laying period than those roaming in the field without improved pasture, fodder shrub and trees (Nitis, 1992). Such better response is probably due to the vitamins and minerals supplied by the improved grass-legume pasture, more plant protein from the seeds of the improved pasture and more animal protein from the white ants living on the plant debris. Lower ambient and soil temperature, higher relative humidity and humus content under the forest and plantation trees induce favourable habitat for wildlife, as Duckett (1976) reported about 20 wildlife species living under the rubber and oil palm plantations. Furthermore, the flowers of grass, ground legume, shrubs and trees become a source of pollen and nectar for honey bees (Nitis et al., 1995).

Benefit to the soil. Vigorous growth of the tropical rainforest accumulated annual litter of 7.5 - 10.5 ton/ha, consisting of 60% leaves, 26% woody branches and 14% others, which in turn increased the humus content of the soil (Chen, 1993). The multi canopy layers of the tropical rain forest intercept the heavy and strong rain drops, which reduces the velocity of the rain hitting the ground. The low velocity of the rain could reduce the soil erosion, while absorption of the water by the humus accumulation could reduce the water run-off. The humus break down into organic matter could enrich the mineral content of the soil.

In the sloping dryland farming area the outer hedgerow of fodder shrubs and trees could accumulate the gravel, while the inner layer of grass and ground legume could accumulate the soil carried out by the downward running of the rainwater. Such integration could reduce the soil erosion by 51%, increase soil field capacity by 18%, increase soil organic matter by 11% and increase soil total N by 5% compared with the land without grass, shrubs and trees integration (Nitis et al., 1995).

Ground legumes, shrub and tree legumes through their symbiotic root nodule bacteria fix N in the air into nitrate N in the soil, and consequently increase the N status of the soil. The soil N status through the root nodule activity of the shrub legume is not only affected by legume and non-legume plants, but also by different species within the legume and non-legume plants. For example, the number, weight and size of gliricidia root nodules in association with cenchrus grass was 64, 93 and 27% bigger respectively than those in association with panicum grass (Nitis et al., 1989). When associated with centro legume, the number and weight of the gliricidia root nodule were 77 and 67 % bigger respectively, while nodule size was 40% smaller than those in association with verano stylo. Furthermore, the effect of grass on the number and weight of gliricidia nodules was 48 and 27% bigger respectively; while the effect on the nodule sizes was 19% smaller than that of ground legume. Different responses were observed for the leucaena.

Under traditional farming practices, although the green manure provided by pruning the shrubs and trees is beneficial, it is not sufficient to increase soil fertility. On the other hand, utilization of shrub and tree fodders by ruminants and the use of their manure as a fertilizer is a more efficient utilization of the carbon and nitrogen in the plant rather than directly using it as green manure (Nitis, 1986). Goat manure contained more N than cattle manure (Rinsema, 1986); and the pelleted form of goat manure decomposed slower than the lumpy form of cattle manure. With such characteristic when applied as organic fertilizer, goat manure will retain soil fertility longer than cattle manure.

Benefit to the land. The higher stocking rate and carrying capacity of the land is due to the integration of improved pasture, fodder shrubs and trees in the silvipastoral system. For example, the land carrying capacity of improved pasture under coconut palms grazed by goats was 2.7 - 3.6 times higher than those grazing native pasture under coconut palms, while for sheep it was 2.8 - 3.7 times (Parawan and Ovalo, 1986). Between the improved pastures, the land carrying capacity of the setaria grass dominant pasture was 34% higher than that of brachiaria grass dominant pasture. This is due not only to more forage supply, but also due to more nutrients and higher digestibility of improved pasture than the native pasture under the plantation crop. The lower carrying capacity of the brachiaria pasture is due to its decumbent habit, so that it is trampled more and become less available and less desirable for grazing.

In the hilly area of the Philippines, 2 ha of land planted with leucaena shrubs alley cropped with annoa fruit trees can support 20 head of growing cattle and when the leucaena is harvested every 40 - 60 days the carrying capacity of the land can be increased further (Moog, 1985). In the dry tropic of Africa cultivation of fodder shrubs and trees in the intensive feed garden system can produce 30 tons DM/ha/year which could carry 4 - 6 head of small ruminants (Atta-Krah, 1989). In dryland farming area in Bali Indonesia, integration of improved pasture, fodder shrubs and trees and cattle in the three strata forage system can increase the land carrying capacity by 52%; while the land stocking rate during the 4 month wet season and 8 month dry season increased by 45% and 30% respectively compared with the land without improved pasture, fodder shrubs and trees (Nitis et al., 1995).

Benefit to the farm and farmer incomes. Higher farm income can be contributed to by higher output (e.g. the sale of more and bigger livestock, by selling livestock more often so that the turnover is faster, by selling more and better quality of timber, fruit and latex; and lower input (e.g. fertilizer and weeding costs, feed costs) while the higher farmer income can also be contributed to by additional off-farm jobs. For example, in the humid tropic of Malaysia, with stocking rate of 10 sheep/ha in young rubber and 16 sheep/ha in mature rubber the profit was 96% higher than the rubber without sheep, which was due to the sale of livestock and saving of weed cost (Anni et al., 1985). In the three strata forage system (TSFS) dryland farming area in Bali, Indonesia, the gross margin for cattle was 30% higher and the farm income was 30% higher than the traditional system (Nitis, 1992). Since the TSFS farmers have more time to do off-farm job, the farmer income was 30% higher.

In the semi-arid tropic of Western India, planting 400 trees/ha for wood and fodder on the bund of sugarcane fields, lead to 25 - 30% increased annual income of the farmers (Hegde, 1991). In the hot arid region of India, the net annual return from silvipastoral systems was 50% higher than the net annual return from annual crops (Gupta, 1993).

Most, if not all, smallholders recognise the importance of fodder shrubs and trees in reducing their cash expenses. A case study carried out in a smallholder dryland farming area in Bali Indonesia showed that by integrating shrub and trees a farmer can save IDR 523,000/ha in the form of fodder (37%), fuelwood (20%), fruit (42%) and farm implement (1%) (Nitis, 1985). In a hypothetical illustration of fodder production from 5 trees planted on barren land and along the bund of a smallholder field, the benefit-cost ratio was 3.12 (Amir, 1989).

Benefit to the environment. The integration of shrub and trees in the silvipastoral system reduces the air temperature, reduces the wind speed and increases the relative humidity, creating a pleasant environment. For example, ambient temperature under the plantation crop canopy in the wet tropic of Malaysia was 1 - 2^{o}C lower and relative humidity was 1 - 6% higher than in full sunlight, while leaf temperature was 0.6 - 1.5^{o}C lower and soil temperature was 1 - 2^{o}C lower than the grass legume pasture in the open (Wilson, 1991). The potential evapotranspiration under the acacia canopy layer above the panicum grass in the dry tropic of Africa was 50 - 70% lower than that above the panicum grass in the open (Le Houérou, 1978).

In the farmland tropical forest in Haenan island of South China, a pleasant environment was established due to the wind speed at ground level being reduced by 30 - 40%, evaporation being reduced by 30%, while relative humidity increased by 10 - 20%, and there was a reduction in the occurrence of sand storms and the momentum of dry and torrid winds (Wang, 1991).

Using livestock to graze regularly the weed under the plantation crops instead of using weedicide may reduce environmental pollution, which is otherwise due to the residual effect of the weedicide.

SOME CONSTRAINTS AND POSSIBLE MEASURES

Even though some benefits have been gained by the plant, animal, soil, land, farmer and environmental components of the silvipastoral system, there are some weakness associated with socio-economic, socio-cultural, biological, ecological, technological and institutional aspects of the system.

Socio-economic. Due to limited input and resources, income is just enough to meet the daily needs of the smallholder farmers. Therefore, very small working capital is available for the expansion of the silvipastoral system. Financial support can be obtained through rural bank credit certified by the farmer cooperative and farmer group.

In the wet tropics land is used intensively for food crop production, so that no land is specially allocated to grow grass and legumes or shrubs and trees for fodder. Strategic planting the bunds of the field, terrace of the sloping land and the waterways with fodder shrubs and tree legumes could overcome the feed shortage, particularly during the dry season.

Seasonal food crops are usually not sold but kept in storage to meet daily needs, while seasonal fruit crops which are in over supply get low prices from the middlemen. Similarly also for livestock, when sold to meet the occsional need get a low gate price from the middlemen. Farmer cooperatives could organize collective marketing to stabilize and standardize the price of such commodities.

Socio-cultural. Some traditional farmers consider cattle as “cold animals”, since the plants eaten will not die; while goats are considered as “hot animals” since the plants eaten will die; so that with such an attitude, farmers prefer to keep cattle than goats. This is presumably due to the eating habit of the cattle, since cattle bite with their tongue so that the bud is not cut, whereas goats bite with their dental pad thereby eating the entire bud. Cut and carry system in the smallholder farm or low stocking density and lower grazing pressure in the commercial farm can be practised.

The attitude that cattle are a “cold animal” and goat a “hot animal“ makes the farmer consider cattle as the first class animal and goat as the second class animal. Consequently when cattle and goat are kept on one farm, cattle are fed grass while goat are fed shrub and tree fodders, despite the fact that the former feed usually contains less CP than the latter (Nitis, 1986). Some ethnic groups consider shrubs and trees as holly plants so that they are not lopped for fodder, while others are reluctant to keep shrubs and trees because they are believed to be inhabited by evil spirits (Blain, 1985). Persuasive approaches by GO and NGO extension workers could remedy such misconceptions.

In some traditional silvipastoral systems the conventional laws enforce that in intensive wet land farming area crop be given more priority than livestock, so that when the livestock eat the plants the owner of the livestock will be fined (Nitis, 1986). However in the extensive dryland farming areas the opposite is true, in that farmers who owned the plants get no compensation.

The landless livestock keeper in the suburban town, the backyard livestock holder in the village and the smallholder farmer during the dry season each claim the right to lop the fodder shrubs and trees along the road side, on communal land and public places, so that it is not uncommon that conflict is caused in the community. The special land right law will be more effectively implemented when organized by the farmer, social and religious groups in those community.

Biological. Lowry (1989) in reviewing the toxic factors in shrub and tree podders, problems and methods of alleviating them in animals stated that the problem of inert toxicity in potential forage plants is one end of a continuum of effects that include aversion responses, reduced intake or digestibility and induced deficiencies. All these effects are caused by secondary constituents/compounds not involved in essential metabolism and found only in particular plant species. Secondary compounds affect the use of tropical trees and shrubs as feed more strongly than most other forages. In particular, phenolic compounds may occur at very high levels. Most secondary compounds appear to have adaptive value to the plants in controlling predation by vertebrate or invertebrate herbivores, bacteria, and fungi. They should thus be considered an inescapable component of the fitness of the plant for its particular environment. Therefore, rather than attempting to reduce the level of such compounds (which may reduce the productivity of the plant), it is better to develop methods for overcoming their antinutritional effects on livestock. The first step is to identify the nature and distribution of any adverse factors. Possible means of overcoming them include: “dilution” by using mixtures of species; treatment, such as wilting; supplements, such as sulphate or polyethlene glycol; or the introduction of new or adapted rumen microorganisms. In general, the foregut fermentation of the ruminant provides a powerful method for detoxifying fodders.

Even though shrubs and trees have been known for their multipurpose roles, however, their genetic potentials for a specific role in the silvipastoral system is not yet fully revealed. For example, a field trial of 16 provenances of *Gliricidia sepium* in the dry land farming area in Bali Indonesia, showed that when grown as a alley cropping system Belen Nicaragua (N24) provenance showed the best response (Sukanten et al. 1995a), when grown as a fence system Retalhuleu Guatemala (G14) provenance showed the best response (Sukanten et al., 1995b), and when grown as a guardrow system Pontezuelo Columbia (C24) provenance showed the best response (Puger et al., 1996) measured in terms of fodder yield and leaf retained during the dry season.

Fodder shrubs and trees are generally quite resistant to disease and pests. However, a psyllid (*Heteropsylla cubana*) outbreak was reported in Hawaii in 1984 and in Asia and the Pacific regions in 1985 (NFTA, 1989). Control measures using stable resistant leucaena varieties, effective predators, insecticides and management practises have been effective to varying degrees. In some areas in Indonesia, *Gliricidia sepium* is infested with aphids (*Aphis craccivora)* particularly at the onset of the rainy season, that causes blackening of the leaf surface and in severe cases causes the death of the leaf primordial and shedding of the young leaves (Nitis, 1992). The aphid exudate causes yellowing and even death of the *Cenchrus ciliaris* grown with the gliricidia. Evaluation of the 16 provenances of *Gliricidia sepium* showed that 3 provenances (G14, N14, C24) are quite resistant to aphid infestation.

Ecological. In the humid and sub-humid wet tropics apart from the heavy rain causing leaching of the soil nutrients, low light intensity under the tree canopy could reduce the yield of the understory crops; while in the semi-arid and arid dry tropics the low rainfall and intense sunlight could reduce the yield of the pasture, shrub and trees. Shade tolerance and drought resistant plants have been identified that could adapt to such climatic conditions.

In the low lying area water lodging, and in the hilly area, cold weather, could reduce the yield of the pasture, shrubs and trees. Plants that could tolerate water lodging and sub-tropical plants that could adapt to hilly areas have been identified to suit such topographical conditions.

In the wet tropics trampling may cause soil compaction, while in the dry tropic grazing may damage the young shrubs and trees in the silvipastoral system. Various measurs to overcome some of these problems have been reviewed by Reynolds (1995).

Technological. One reason why the technology is not accepted and adopted by the farmers is because it is too complicated and too costly for the farmers. For pure research sophisticated equipment can be used, for example, the use of embryo transfer for livestock improvement, the use of tissue culture for plant improvement, simulation model and linear programming to study the socio-economic impact. When it comes to the farmer level, the technology applied should be appropriate, easily transferable and repeatable. For example, for smallholder farmers the forage and fodder isfed preferably on cut and carry and/or tether grazing systems, while for the commercial farmer rotational, differed and rapid folded grazing will be more appropriate. The fodder shrubs and tree should be lopped twice during the 4 months wet season and twice during the 8 months dry season so that fodder is available year round as standing green (Nitis, 1989). Formulation of a simple regression equation is possible by measuring stem diameter to predict shrub and tree yields and by measuring body dimension to predict the live weight of the ruminant.

Institutional. Even though many shrubs and trees have been used in the wet and dry tropics, only some have been researched for their suitability for the silvipastoral system. Furthermore, the research and development carried out are segmental rather than holistic, so that when formulated and applied as a package technology it often causes economic loss to the farmer and desertification of the land. Co-ordination between the policy maker, support groups (including researchers, extentionists and financiers) and practicioners should be targeted to achieve the goal of a sustainable agroforestry system (Mellink et al., 1991), and possibly silvipastoral system.

SOME POTENTIAL SUSTAINABLE SILVIPASTORAL SYSTEMS

The followings are some of the potential sustainable silvipastoral systems that could increase not only timber, energy, food and feed productions, but also could conserve the environment. Even though the role of the silvipastoral system is multipurpose, its suitability to climatic and topographical conditions (Table 1), feeding management (Table 2) and production function (Table 3) varies among the systems.

Intercropping system. The fodder shrub and tree legumes can be grown anywhere among the plantation crop as shade or as climber with the number of shrubs and/or trees varied from 100 - 300 plants/ha (Nitis, 1986). In the early growth stage of the plantation crop, livestock production can be important, while as the plantation crop canopy closes, fruit and latex production become dominant. No timber is produced regularly in this system.

Alley cropping system. This system consists of growing a food crop between 2 rows of frequently pruned fodder shrub legumes. The pruned foliage can be used either as green manure or as fodder for livestock in a cut and carry system. The alley grazing, a variant of the alley cropping, is when improved pasture is grown instead of a food crop (Atta-Krah, 1989) and the shrub is browsed instead of cut and carred. To balance the system only 25% of the foliage is used as fodder, with a rotation of 4 years food crop and 2 years forage for grazing. No timber and fruits are produced in this system.

Taungya system. Taungya is a Burmese word meaning hill cultivation and is derived from traditional shifting cultivation. Improved taungya is growing strips of fodder shrubs and trees with a food crop between the band of timber trees on the sloping land used for forestry (Wiersum, 1982). The pruned foliage of the shrubs and trees become cut and carry fodder supplement for the livestock. When the forest canopy closes, timber become the dominant product.

Sorjan system. This is growing fruit trees, fodder shrub and trees on a strip of raised bed from soil dug up to form a shallow bed for food crop production. The soil is laid down alternately, on low lying areas (Kepas, 1988). The foliage of the shrub and trees can be lopped for cut and carry feeding livestock during the dry season. Timber becomes the complementary product.

Intensive feed garden (IFG) system. This is a cultivation of fodder shrubs and trees in a sole stand or in combination with grass and managed intensively to provide fodder for livestock (Atta-Krah, 1989). The grass can be grazed and the fodder shrubs and trees can be browsed when the stand is still young and lopped for cut and carry system when the fodder shrubs and trees mature. No timber or fruit are produced.

Fodder bank system. The fodder shrubs and trees can be planted on either the embankment of water ways, in clusters on sloping land, on critical land or fallow land or on land not used for food crop production (Nitis, 1986). They can be planted in either sole stands of leguminous or non-leguminous fodder shrubs and trees, or in combinations. Forage production is important when the stand is still young and becomes not suitable when the stand becomes mature. Grazing can be applied when the stand is still young, and when the stand is mature a cut and carry system is more appropriate.

Home plot system. This system is a complete integration of farm house with shrubs and trees, pasture, food crop and livestock in a small area of land (Anon, 1990). In this system the border of the farm compound is totally planted with shrub and trees with a strip of grass inside the border. The area inside the border is used for housing of the farmer family, livestock shed, fodder shed, for growing food crops and for growing forage a for protein bank and forage for an energy bank. Livestock feeding is the cut and carry system. This system is now being tested in transmigration areas in Sumatra, Indonesia.

Sloping agricultural land technology (SALT) system. This consists of alternative strips of annual food crop and strips of fodder shrub or tree legumes along the contour line on the upland area (Boyabos, 1991). In the Philippines, where the system originated, the land used is 40% for agriculture, 20% for forestry and 40% for livestock, particularly goats in a cut and carry system.

Savannah system. This is integration of shrubs and/or trees either singly or in a cluster among the natural grass in an extensive dryland area in the dry tropic (Nitis, 1986). In its improvement the natural pasture can be sown with improved grass-legume pasture and the native trees can be replaced with timber trees (savannah timber land) or the native trees can be replaced with fodder shrubs and trees (savannah fodder land).

Three strata forage system (TSFS). This is a technique of planting and harvesting grass and ground legumes (as first stratum), shrub legumes (as second stratum) and fodder trees (as third stratum) so that livestock feed is available year round as standing green feed (Nitis et al. 1989). It consists of 0.25 ha land divided into a 0.16 ha core area for either the food crop, plantation crop or forestry; 0.09 ha peripheral area for growing grass-legume improved pasture and 200 m circumference area for growing fodder shrubs and trees. The ruminant feed consists of 65% pasture, 20% shrub fodder and 15% tree fodder during the wet season and during the dry season it consists of 35% forage, 45% shrub fodder and 20% tree fodder. In the semi-arid and arid dry tropics this TSFS can be developed into a mini-ranch by replacing the plants in the core area with improved pasture.

RESEARCH NEED

Basic research is still needed on the mechanism of native plants and animals to adapt to the igh rainfall and low light intensity under the tree canopy in the humid and sub-humid wet tropics; and to the low rainfall, high light intensity and intense sunlight in the semi-arid and arid dry tropics. Results of this research can be used to develop plant and animal hybrid vigour that could adapt to such conditions.

Applied research is still needed on the mechanism of integration of plant, animal, soil and ecological condition through its associative, synergetic and symbiotic association to optimise output with minimal input.

On-farm research is still needed to develop a silvipastoral model that could increase the income and welfare of the farmer in particular and the rural community in general.

STRATEGY FOR IMPLEMENTATION

The degree of the effectiveness of the implementation of the proposed strategy will depend on the socio-economic, socio-cultural, biological and technological improvements and institutional awarness of the region. Some of those strategies are as follows:

1. Strengthen research and development in areas where further improvement of the silvipastoral system is required

2. Establish silvipastoral system demonstration plots at strategic locations for socialization of the plant, animal and technology that could adapt the environment to increase the silvipastoral productivity.

3. Strengthen the affiliation and coordination between the national, regional and international GO and NGO organizations for exchange of information and for interdisciplinary research and development of silvipastoral systems.

4. Increase institutional support for the desired objective, which is in line with the government policy to increase food suppy from plant and animal origins, eradicate poperty in the rural area and reduce land degradation.

5. Optimise integrated land use capacity in both private and public lands for the production of specialised components of silvipastoral system.

6. Identify the specific output of the silvipastoral products for agroindustry outlets and agribusiness market demand.

CONCLUSION

The traditional silvipastoral system has been known and practised for hundreds of years by farmers in the wet and dry tropics to meet farmer needs. In the wet tropic shade tolerance is more important, while in the dry tropic drought resistance is more important for the tree and understory crops in the silvipastoral system. Even though new and non- traditional silvipastoral systems have been developed to not only help meet the increasing demand for timber, energy, food from animal origin, but also to conserve the environment, a more holistic approach should be adopted and research support should be provided to put the new knowledges of silvipastoral system into practice.

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Table 1
Suitability of variants of silvipastoral system to the ecological condition

Variant system[1)]	**Wet tropic**		**Dry tropic**		**Topography**	
	Humid	Sub - humid	Semi -arid	Arid	Low land	High land
Intercropping	**	*	*	-	-	**
Alleycropping	**	**	*	-	*	**
Taungnya	**	*	*	-	-	**
Sorjan	**	*	-	-	**	-
IFG	-	*	**	*	*	**
Fodder bank	-	-	**	*	-	**
Home plot	**	*	-	-	**	*
SALT	-	-	**	*	-	**
Savannah	-	-	*	**	*	**
TSFS	-	**	*	*	*	**

** = Important
* = Complementary
- = Not suitable
1) For descriptions see text

Table 2
Suitability of variants of silvipastoral system to feeding management

Variant system[1)]	Cut and carry	Tethered grazing	Free ranging
Intercropping	**	-	*
Alleycropping	**	*	*
Taungnya	**	*	-
Sorjan	**	*	-
IFG	*	*	*
Fodder bank	**	*	*
Home plot	**	*	-
SALT	**	*	-
Savannah	-	-	**
TSFS	**	*	*

** = Important
* = Complementary
- = Not suitable
1) For descriptions see text

Table 3
Suitability of variants of silvipastoral system to the production function

Variant system[1)]	Plant product			Livestock product		
	Timber, wood	Oil, fruit, latex	Fodder, forage	Meat	Milk	Egg
Intercropping	**	**	*	*	-	-
Alleycropping	*	-	**	**	-	-
Taungnya	**	-	*	*	-	-
Sorjan	-	**	*	*	*	*
IFG	-	-	**	*	-	-
Fodder bank	-	-	**	**	-	-
Home plot	*	*	**	*	*	**
SALT	**	*	*	*	-	-
Savannah	*	-	**	**	-	-
TSFS	*	*	**	**	*	*

** = Important
* = Complementary
- = Not suitable
1) For descriptions see text

Figure 1
Development of silvipastoral system