Economic Assessment of Several Agroforestry System and Land Use Options in Malaysia: A Review

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ABSTRACT

The shortage of log supply became an alarming problem for Malaysia starting from 1995. Similar problem is encountered in the food sector, whereby the import bills has increased from RM4.6 billion to RM10 billion in 1997. It implies that extra effort needs to be done to increase food as well as log production. Agroforestry is one of the ways to solve this problem. Taking this issue into account, the main intention of this paper is to review the current agroforestry systems and land use option in tropical climate especially in Malaysia. This paper does not only review the current agroforestry system but also evaluate the economic feasibility of different types of agroforestry system available in Malaysia as well as for other tropical climate countries. This paper is expected to help the farmers to provide the economic criteria in selecting the right choice of agroforestry system for their farm.

Keywords: *agroforestry system, economic assessment*

Introduction

To a developing country such as Malaysia, timber extraction is important to achieve Vision 2020. The revenue generated from the forest could be channeled for development. At the same time, this sector could provide employment for not only the forest harvesting activities but also for the downstream forest related activities. Knowing that, forestry as a slow renewable resource should be managed properly to ensure enough timber supply for future consumption.

The issue of sustainable forest harvesting has been a great concern. Thang (1985) forecast logs deficit problem eighteen years ago. He highlighted that, logs supply had become deficit after year 1995. For the period of 1996 to 2000, the log supply deficit was 1.08 million m^3 and this deficit in log supply has gone up to 2.43 million m^3 for the period 2001 to 2005 and 3.71 million m^3 for the period 2006 to 2010. Under the Rio Convention, the country has implemented several strategies amongst others, which include sustainable forest management, enrichment of degraded forest and the reduction in the annual coupe. These activities have directly or indirectly reduced the timber and timber logs supply in Malaysia. The consequence of such change is the shortage of timber supply for the wood based industry. It has been estimated that from 2010 the shortfall in demand will be around 12.3 million m^3 per year (Abdul Razak et. al. 2000).

In order to ensure an adequate supply of raw materials for the downstream industries, the Malaysian Government banned the export of logs from Peninsular Malaysia and allowed only timber products (processed or semi processed) to be exported. Simultaneously, the Government has encouraged forest plantations and agroforestry project to be established including rubberwood plantation (Mahmud 1997b). Nevertheless, there is poor response from the farmers because forestry project normally incurs high initial capital, long gestation period, difficult to secure loans and hard to get suitable area. In fact the most crucial things is that, information about agroforestry is lacking (Gorden and Bentley 1990).

A similar problem is encountered in the food sector. The food bill as reported by Ministry of International Trade and Industry shows the gap between supply and demand is increasing each year. The import food bills increased from RM4.6 billion in 1990 to RM10 billion in 1997. The rice import escalated from 330,000 to 580,000 tons, vegetables from 350,000 to 690,000 tons and beef from 41,000 to 71,000 tons (Najib and Mahmud 1999). It implies that extra effort needs to be done to increase the food production.

It is clear that there is a shortage for both wood and food supply for Malaysia, which could be solved through implementing agroforestry projects in Malaysia. Therefore, this paper is going to review about several agroforestry systems available in Malaysia. This information could help the farmers to compare agroforestry system with other plantations or monoculture practices in the country as well as other tropical countries.

Background

Agroforestry is generally accepted as a land use system involving integration of woody perennials with agricultural crops and/or animals or vice versa. The main purpose of agroforestry is to maximize productivity on the same piece of land. In the Malaysian context, agroforestry involves intimate combinations of agricultural crops (annuals, biannual and even perennials), animal rearing (eg. sheep, cattle and deer) and tree species (including forest species, Hevea and medicinal plants) aimed at providing additional income and early cash flow.

Agroforestry in Malaysia, as in other parts of the world, is an old farming practice. The earliest approach involves mixing of various agroforestry components on vacant land usually around the home garden. The agroforestry components include fruit trees, bamboo, poultry, vegetables and other short term crops as well as animal rearing. However these combinations are traditional and unsystematic and the practice is solely to subsidise the farmers' basic needs of food and fuel.

The commercial scale agroforestry in Malaysia was believed to be first initiated in 1920's with the planting of rubber trees in coffee plantation. In this system, rubber trees were planted in the inter-rows of the coffee plants. But the approach, although economically viable, did not last long. As the market value of latex increased and coffee price dropped, the coffee plants were removed leaving the rubber trees under monoculture. Since then, the planting of tree crops is in the form of monoculture and has been successful with perennial crops especially rubber, cocoa and oil palm.

However, in recent years, resulting from the declining return from the monoculture plantations coupled with the need to obtain earlier income, agroforestry in the form of intercropping or integrated farming has emerged as an important land use system (Mahmud 1997a,b,c). It has been established mainly in immature cocoa, coconut, rubber and oil palm smallholdings and estates. The added components include short term crops such as pineapple, vegetables, chili and maize. In some plantations, livestock rearing (eg. sheep and poultry) and mushroom cultivation are commercially introduced as agroforestry. Generally, they are proven technically feasible and economically viable during the early immaturity phase of the main crops. As the tree canopy closes, the yield of added component decline and the whole integration system ceased.

In the Malaysian forestry sector, commercial agroforestry was first initiated in 1950's through the Taungya system. Taungya is referred to as a temporary agricultural intercropping in the forest plantation and usually practised as a mechanism of reforestration and as an approach to control shifting cultivation. In this system the farmers were allocated degraded land and allowed to plant cash crops and timber species as specified by the government. Once the area becomes uneconomical due to the closing canopy, the farmers had to abandon their plots. Although the system was shown as cost-effective in the establishment of forest plantation, the farmers tend to focus more on their crops and usually neglect the forest species. Due to this constraint and in addition to the allocation of new agricultural land to these farmers in the 1970's, the system was terminated.

In order to make agroforestry sustainable, avenue or hedge planting system has been developed mainly in rubber plantations. Basically, it involves planting of tree crops in single, double or triple rows in the form of hedges with wide spacing between the hedges. The wide spaces provide long term economic activities without compromising on the tree stand, growth and yield. Such system is being practiced by the smallholders and some estate owners with the planting of fruit trees and even timber and medicinal plants in the wide avenue. Other permanent agroforestry systems that are suitable in Malaysia plantations include perimeter planting and block planting.

Choice of Agroforestry Components

The right choice of components is an important element in the development of agroforestry. In general, the components must be adaptable, adoptable, sustainable over longer periods and economically viable. It is always safest to select the components that do not compete for nutrients, water, sunlight and space. Should there be indication of competition, it should be minimal and does not seriously affect total land productivity. For a successful agroforestry, the components must have commercial value and are highly demanded locally and overseas. Last but not least, the components chosen should be easily established and maintained within the capability of the potential users in term of labour and capital availability.

Timber Species

The timber species suitable for agroforestry should have the following characteristics:

- Fast rate growth
- Light branching and narrow crown
- Strong and deep root system
- Efficient nutrient pumps
- Self-pruning characteristic
- Resistant to drought, diseases/insect/pest attack
- Soil improving characteristics
- Good coppicing
- High survival under adverse conditions
- Multiple use
- Phenology, rate of litter fall and decomposition should have positive effect on soil.
- Available planting materials

In Malaysia, teak (*Tectona grandis*) and sentang (*Azadirachta excelsa*) have been identified as suitable timber species for commercial production. Both these species have been reported economically viable under monoculture and even in the form of agroforestry. Under monoculture, the estimated Internal Rate of Return (IRR) is 16.23% for teak and 15.13% for sentang. Mixed planting of sentang or teak with Hevea for latex and rubberwood through suitable agroforestry planting system produce IRR exceeding 15% which is more than the planting of Hevea under monoculture. Other species that can be considered for agroforestry include *Khaya ivorensis* (African mahogany), *Dyera costulata* (Jelutong) and some dipterocarp species such as *Shorea leprosula* (Meranti tembaga), *Shorea parvifolia* (Meranti sarang punai) and *Hopea odorata* (Merawan siput jantan).

It is important to note that the above timber species have long gestation periods of more than 15 years before they can be harvested as timber products. This factor will affect cash flow and may be serious if they are planted in a large portion in the agroforestry system. Hence, the planting of timber species have to be at a reasonable quantity and in an appropriate agroforestry design. The planting of timber species in the agroforestry system is solely for the purpose of providing bonus income. In order to generate additional income, it is preferred to include short term crops and/or animal rearing or medicinal plants in the agroforestry

system. Other important factors which have to be taken into consideration in the use of timber species as agroforestry components are site suitability, knowledge on growth habits, establishment and maintenance requirement and markets and market value.

Medicinal Plants

The use of plant-based products for disease prevention and treatment has become increasingly popular. It is estimated that approximately 80% of the population in developing countries rely chiefly on traditional medicines for primary healthcare of which a major portion involves plant extracts. The annual sale values of herbal products in 1985 were around RM107.5 billion in Europe, Japan, Australia, Canada and the U.S. In Malaysia, the yearly market value of traditional medicine was between RM1-2 billion in 1995.

The demand of the raw materials for the production of medicine and herbal products is expected to increase. Currently, the herbal materials are collected from the wild, with the quantity expecting to decrease in the future. The alternative approach is to plant them through agroforestry (Mohd Ilham and Mahmud 1998). Among the herbal materials recognised with commercial value and agroforestry compatible is Tongkat Ali. The root of this plant is used for treating body pain, hypertension and as an aphrodisiac, while a concoction of roots and bark may be used for treating fever, post-natal wounds, wounds, ulcers, syphilis, malaria, high blood pressure and diabetes. Other herbal materials with potential for commercial cultivation in agroforestry system include *Labicia pumila* (Kacip Fatimah), *Andrographis paniculata* (Akar cerita), *Kaempferia galanga* (Cekur), *Cucurma xanthorriza* (Temulawak), *Casia alata* (Gelenggang) and *Morinda citrifolia* (Mengkudu).

Agriculture Crops and Animals

Almost all annual and biannual crops, grown widely as monoculture, and animal rearing can be integrated in tree plantation. The popular crops currently being commercially planted in the available spaces of the tree plantation are vegetables, maize, watermelon and sugar cane. Animals that can be reared under oil palm, rubber, coconut and even forest plantation include poultry, cattle, goats, sheep and deer. Examples of agroforestry system involving short term crops and animals being practiced by farmers are shown in Figure 1.

1a.

1b.

1c.

1d.

Fig. 1: Examples of Agroforestry Involving Short Term Crops, Medium Term Crops and Animals.
1(a) Vegetable + sentang. 1(b) Pineapple + rubber. 1(c) Sheeps + rubber.
1(d) Tongkat Ali + rubber.

Combining short term annuals with tree crops has been shown to be technically feasible and economically viable. The additional income varies depending on crop mix. Examples of such integrated system proven to improve overall income are shown in Table 1. The additional return of integrating agriculture crops in forest plantation may be similar to agroforestry rubber + short term crop. This will provide early cash flow and some income at least the first 3 to 5 years of the immature phase of the timber species.

Block Planting

This option involves block planting of timber species in hilly terrain and difficult areas and agricultural tree crops on suitable topography. This system is appropriate for large plantations where the land topography consists of mixture of flat, rolling, undulating and hilly terrain. Depending on the land-forms, the planting can be implemented at suitable

Table 1: Income Improvement of Some Selected Agroforestry System.

Main Crop	Value Added Components	Period from establishment (main crop)	Mean additional income with Agroforestry (RM)	Source
Rubber (1.8 ha)	Vegetable (0.2 ha) + Banana interow	7 years	RM 580/month	Kadir (1999)
Oil Palm (1 ha)	Sugar cane - intercrop	22 months	RM 533/month	Suboh et al. (1999)
	Banana - intercrop	20 months	RM 832/month	Suboh et al. (1999)
	Pineapples - intercrop	15 months	RM 231/month	Suboh et al. (1999)
Oil Palm (4 ha)	Cattle	Mature Plant	RM 216/month	Mohd. Nasir (1999)

combinations e.g. 20:80 of timber species to agricultural plants (e.g. oil palm and rubber) in estate (Figure 2) or 80:20 of timber species to agricultural tree in forest plantations.

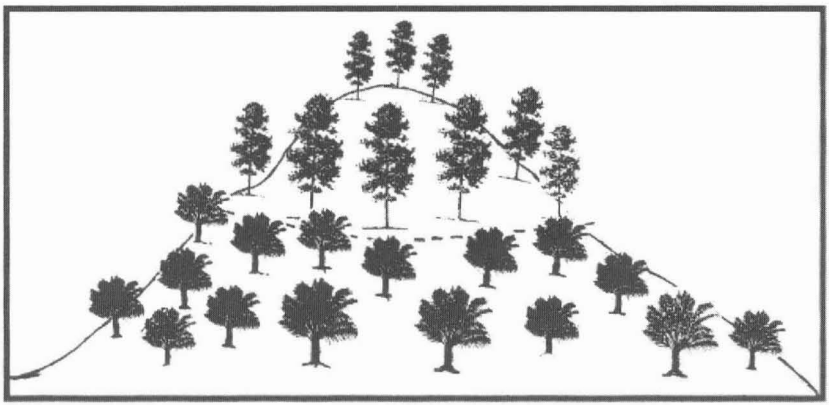


Fig. 2: Agroforestry Block Planting for Agricultural Tree Crop Plantation

Alternate Row

This option involves cultivation of short term crops and rearing of animals in the inter-row of the tree crops (Figure 3). The option is commonly practised with immature rubber, oil palm, and even forest plantation. It is confined in areas with undulating and flat topography. Examples are shown in Figure 3 and these have benefited the farmers at providing early income at least for a period of three years.

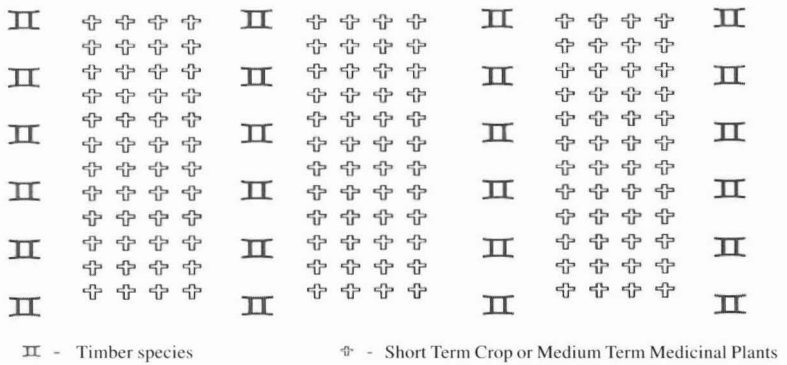


Fig. 3: Alternate row Agroforestry System Random System

Because most forest plantation is sited on difficult location and usually in the interior away from the market outlets, combining short term crops with tree species through alternate row system is not suitable. The preferred approach, therefore, is to occupy the inter-row space include thinning area with non-timber species such as medium term shade tolerant medicinal plants, bamboo and rattan.

In this system the timber species are planted randomly on all vacant areas of the large tree crop plantations. The vacant spots include areas left idle due to disease and wind damage as well as available spaces around factory, workers' quarters and office buildings. Species to be planted should be of high quality timber and resistant to disease and wind damage. If all the vacant spaces are occupied, the whole agroforestry system will appear as in Figure 4.

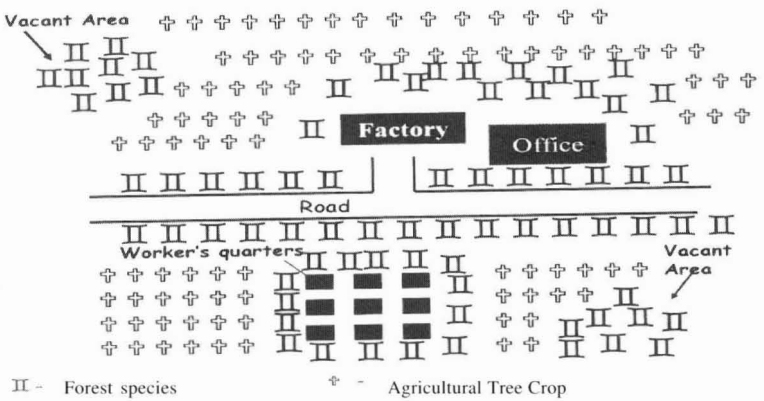


Fig. 4: Random Agroforestry System

Perimeter or Border Planting

Perimeter or border agroforestry refers to the planting of timber and/or non timber species along river and roadside as well along borders of agricultural crop plantations and animal pastures. Selected forest species can be planted around paddy field, oil palm, rubber, fruit trees and cattle range acting as landscaping or living fence but eventually harvested for timber and non-timber species. The agroforestry border designs appropriate for the various type of agriculture systems are shown in Figures 5 and 6.

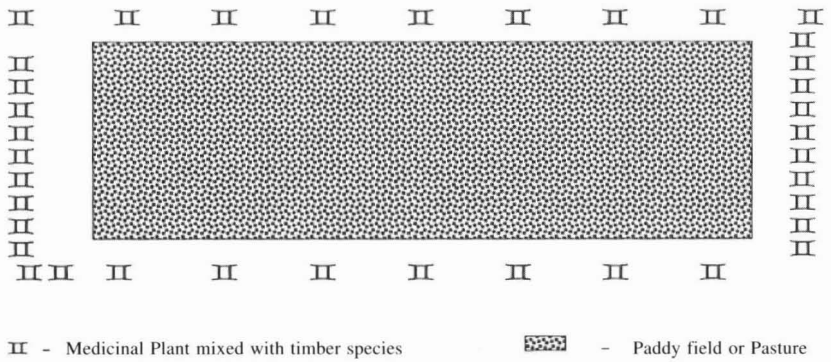


Fig. 5: Border Planting in Crop Field

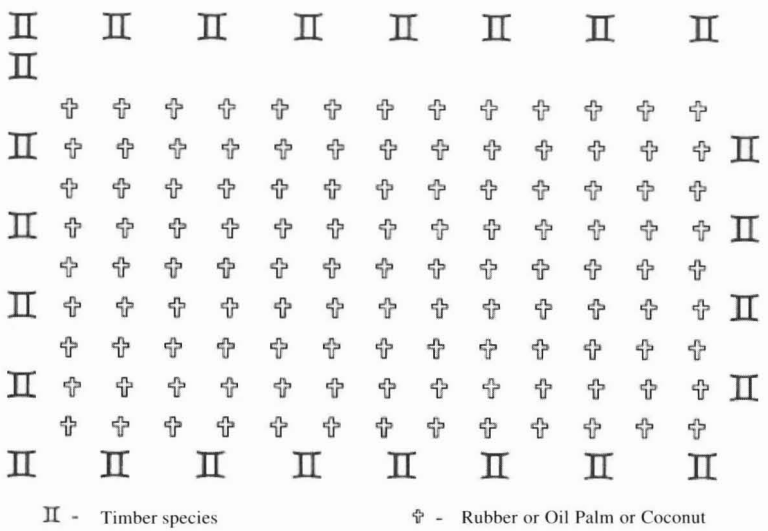


Fig. 6: Border Planting for Tree Crop Plantation

Taungya

This is referred to as a temporary agriculture cropping, usually short term crops in the early stage of forest plantation establishment. In this system, land which is, usually a degraded forest, will be allocated by the government with specific conditions. The farmers are allowed to plant crops as well as timber species as specified and required to abandon their plots once the canopy of the timber species closes. This system is adoptable only when there are (i) adequate suitable land (ii) presence of willing land-hungry farmers (iii) ready market for the agricultural crops (iv) security against wild animal. The approach has been proven successful in Thailand, Burma, India and Philippines as a mechanism for reforestation and control of shifting cultivation.

Taungya may be adopted as an approach towards establishing timber plantation on ex-tin mining land. Initially, this land is cultivated with vegetables and fruit trees such as guava and 'jambu air' for a period of 3 years. Once the soil is conditioned by the agricultural activities, timber trees are then planted at moderate density of around 500 trees/ha and maintained together with the existing agricultural crop. When the tree canopy is about to close, the agricultural crops have to be removed and replaced with shade tolerant medicinal plants such as Tongkat Ali. The phases of Taungya development on ex-tin mining area is shown in Figure 7.

Hedge Planting System

A new hedge planting system has been developed by Malaysian Rubber Board to sustain productivity of the intercrop over longer period in rubber plantation. In this system, the distance between rows e.g. rubber has been widened from the normal 6 to 9 m to 18 or 25 m while distances within the trees in the row, has been reduced from 3 to 4 m to 1.4 or 2 m (Abdul Ghani et al. 1991). At a planting distance of 18 x 1.4 m with one row hedge on hilly areas, or 22 x 3 x 2 m two rows hedge on flat to rolling terrain, the number of trees are maintained at an economic level of 400 trees/ha. The wide inter-hedge can, therefore, be planted with tree crops such as fruit trees and also, timber species. Examples of agroforestry hedge planting design suitable for rubber, timber species, fruit trees and short term crop combinations are shown in Figure 8.

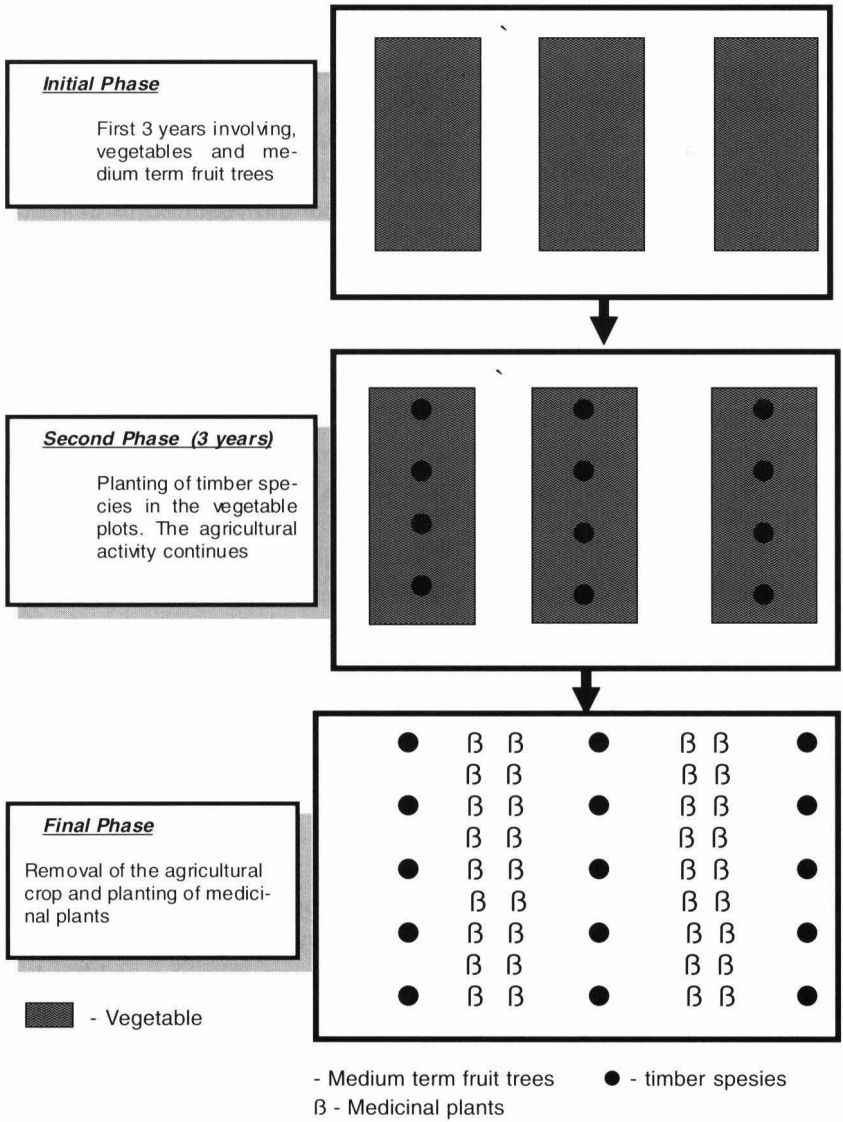
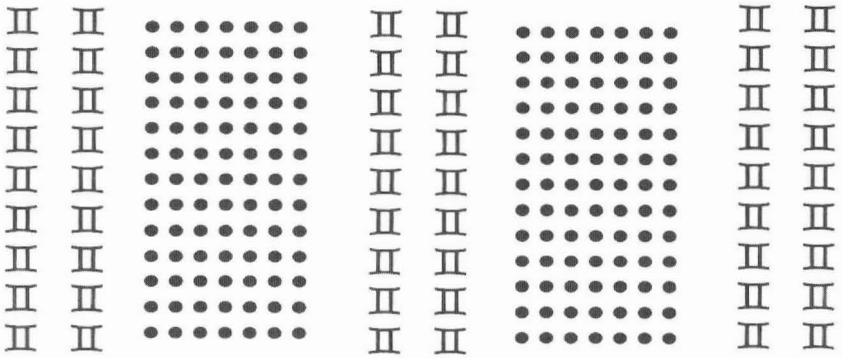


Fig. 7: Taungya System on Ex-Mining Land



II - Tree Crop (Rubber or Timber Species) as hedges

● - Agricultural Crop (short term crops, fruit trees, animals, medicinal plants) in the avenue

Fig. 8 : Hedge Planting Design for Rubber or Timber + Agricultural Crops: Hedge Planting Distance – 3 X 2 m (Double Hedge) on Flat or Undulating Area Or 2 m Apart (Single Row Hedge) Only Hilly Terrain with Avenue Distance Between 16 To 25 m.

Timber species can also be integrated with oil palm through a modified planting system. In general, this can be done through the following agroforestry systems of planting:

- Double avenue planting
- Hedge planting system

In the double avenue planting system which was developed by the Palm Oil Research Institute of Malaysia (PORIM), timber species are planted in the centre of an avenue which has a width of 15 m (50 ft). Oil palm, which provides the early cash flow, is planted in a triangle of 9 x 9 x 6 m (30 x 30 x 20ft) at a density of 136 plants ha^{-1} (Figure 9).

Oil Palm Hedge	:	9 x 9 x 6 m
Tongkat Ali single row	:	3 m apart
Timber spesies single row	:	6 m apart

In the hedge planting system, the existing density of oil palm can either be retained or reduced slightly by 3 to 6% to accommodate the timber species which are planted in the centre of a wide inter-row of 14-16 m. For ease of harvesting, the high value timber species fell at the same time as the falling of oil palm's value.

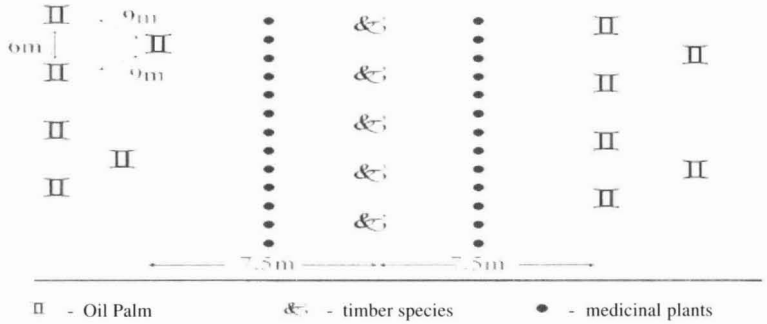


Fig. 9: Proposed Hedge Planting Design for Oil Palm Agroforestry

In addition, for added value in both systems of planting, fast growing species for early harvest for the wood biomass at three or four years, can also be incorporated at specific distances on either side of high value timber species. Timber species grown for logs or wood biomass over a short rotation, can also be integrated with fruit trees through the hedge planting system in which the timber species are planted along the hedges and fruit trees planted in the wide inter-row at specific distances between the timber hedges (Figure 9).

Establishment and Management Inputs

For a successful development of agroforestry, the various components must be established and maintained according to recommendation similar to that under monoculture. Generally, the development involves proper land preparation, fertilizing, weed and pest control. Similar agricultural inputs should be applied to forest species in the agroforestry system. These inputs are necessary to ensure that the plants and animals grow vigorously under optimal condition so as to produce maximum productivity. In order to facilitate accessibility during development and at harvesting, the plantation should be serviced with good in-field road system.

Potential End Users and Appropriate Agroforestry Design

The main potential users of agroforestry will be the smallholder who own uneconomic size holding and practise monoculture planting. They

constitute the bulk of poor farmers and suffer the most each time they obtain diminishing return due to factors such as price decline and rising production cost. The groups of farmers under these categories are paddy planters, coconut farmers and lately, the rubber smallholders.

Incorporating value added activities into their holding through agroforestry can improve income. The appropriate agroforestry designs include:

- Rubber + short term crops + forest species (medicinal plants)
- Rubber + short term crops + animal rearing (such as poultry and sheep) + forest species (timber or non-timber species)
- Paddy + duck rearing/vegetable farming + forest species on bunds
- Coconut + short term crops + forestry species.

Agroforestry involving only timber species with long gestation period is not suitable for active smallholders as this will further deteriorate their monthly income. However, the system can be useful for tenant farmers or absentee landowners who have some interest in timber production. It is believed that the number of such smallholders are increasing each year. In their case, the agroforestry option can be perimeter planting or alley cropping of high value timber. The return from timber will be a useful capital during replanting and immature phase of the perennial crops (e.g. rubber).

Another group of potential users are the estate owners who require timber for their own wood-based industry or who need forest species including medicinal plant as added value in their monoculture estates. The appropriate agroforestry system is to plant timber species such as sentang and teak on those available land, unsuitable for oil palm or rubber. These would include areas such as on very steep slopes or very low-lying areas that are difficult and demand high labour cost if economic crops such as rubber or oil palm are grown. They may also plant timber along estate road perimeters or in available spaces of the workers quarters or plant selected non-timber forest species in the inter-row.

It is envisaged that the most important clients of agroforestry will be the investors on forest plantations. They need some form of mechanism that is bankable which can provide early and continuous return during the long gestation period of the timber species. Incorporating agriculture crops or medicinal plants or animals in modified planting system with forest species can be a solution for a sustainable investment venture. Such system will go a long way in the government's or private sector's efforts in enhancing timber supply.

Benefits of Agroforestry

The benefits of agroforestry in tree plantations are many. It can maximise land usage and, hence, provide additional income, early cash flow and better return of investment. A well designed agroforestry can be adopted as a mechanism in the establishment of forest plantation and this in turn will encourage private sector involvement and thereby improves utilization of idle land as well as degraded forest.

Agroforestry also plays important roles to the forest environment and social activities of the forest dwellers. It improves biodiversity, increases biomass production and provides better microclimate. Where agroforestry is developed on damaged forest, resulting from activities such as overlogging and shifting cultivation, it will provide a permanent resettlement center. This, among others, will discourage collections of items such as bamboo, herbal plants and rattan over wide areas and hence leave the forest undisturbed. In essence, agroforestry has the potential to transform wasteland, uneconomic agricultural land and disturbed forest into an integrated productive-protective system. The benefits of agroforestry are summarised as follows:

Economic and Social

- *Increased income opportunities*
  Higher and better distribution of income with agroforestry practices is assured.

- *Variety of products and/or services*
  From the same piece of land, a variety of products can be produced and services provided. These include, food, wood, medicinal products, shade, ornaments, windbreak etc.

- *Crop diversity and reduced risk*
  Diversity of crop helps to reduce the economic impact of price fluctuation of any single crop and as indicated earlier, will also help to reduce the risk of crop failure.

- *Reduced establishment costs*
  Cost of establishing long term tree crop can be reduced when trees and other crops are established together.

- *Reduced weeding requirements*
  The presence of a tree canopy can reduce light levels at ground level, often reducing weed growth of light demanding weed species.

Biological

- *Increased space utilization*
  The planting of crops that differ in light requirements, root development and height allows for a more efficient use of solar radiation, root development and nutrients.

- *Improvement of soil chemical, physical and biological characteristics*
  Soil improvement and the benefits of enhanced nutrient cycling or "pumping" to the surface, soil nutrients in sub-soils in agroforestry practices that use deep rooted tree species.

- *Increased productivity*
  Aggregate production from agroforestry mixture is generally greater than that from monoculture (Nair 1984).

- *Potential reduction in soil erosion*
  Multistoried canopy in agroforestry system can reduce rainfall erosion through tree canopy, ground cover of annual crops, grass pastures, or legumes and surface litter layer (Young 1986).

- *Reduction in microclimate extremes*
  Tree canopies modify temperature and moisture extremes (MacDicken & Vergara 1990).

- *Reduced risks of crop failure*
  Risk of crop failure can be reduced by plant diversity (Ewel 1986).

Conclusion

Worldwide, agroforestry system is fast becoming recognised as an economically viable, environmentally sound and socially acceptable system which is capable of yielding both wood and agricultural products on the same piece of land hence appropriate for both the estate and smallholder sectors.

Agroforestry, when properly implemented, has the ability to overcome the early cash flow problem associated with the planting of timber species, through the integration of agricultural crops. In the process, good returns from the harvest and sale of selected, high value timber species are also ensured.

Specific agroforestry systems can also be designed whereby selected fast growing timber species are grown either over a short duration for wood biomass or targeted specifically for specific wood-based industries.

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