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Economic Potentials of Legume Crops in Plantation Management

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6.1 Introduction

Legume crops are commonly used for special purposes in plantation management such for shading, supporting tree, windbreaker, and cover crops. Besides its main function as complement plant, legume has another benefit for maintaining soil fertility and productivity. The leguminous plants are very common in plantation management because of their capacity to produce root nodules. Through microbial process, legume bacteria could fixate nitrogen from the air and convert it into special compound that can be utilized by plants. The literature has suggested that not all legumes are able to form nodules. Only genera in family of *Papilionaceae* are mostly (77%) found to be nodulated, and genera in *Mimosacea* are lesser (55%), while the least is (15%) for genera in *Caesalpiniaceae* (Simanungkalit, 2004). All of legumes cover crops are belong to *Papilionaceae* and most of them have been reported able to form nodules. Shading trees in plantation crops are mainly of *Papilionaceae* or *Mimosaceae*.

The chapter examines the economic potentials of legume crops – both legume cover crops and legume shade trees – in plantation management in Indonesia. First, the

general roles of legume crops in Indonesian plantation will be examined, and followed by explanation on legume crops and legume shade trees. Economic value of N-fixation of legume cover crops and legume shade trees are estimated using some assumptions based on previous research available.

6.2 Roles of Legume Crops

The roles of legume crops in plantation include its functions as cover crops of the land and as shading trees for some estate crops. Indonesia is well known as exporter of various industrial crops produced from large area of plantations and smallholders. Four commodities that commonly use shading trees are coffee, cacao, black pepper, and vanilla. Legume cover crops are commonly used in rubber plantation and oil palm plantation. In Indonesia, total area of large estate and smallholder plantation of coffee 1,389,900 ha, cocoa 828,600 hectares, black pepper 204,068 hectares and vanilla 12,100 hectares.

Observation in Lampung showed only 50 percent of coffee and cocoa fields used shading tree with the intensity coverage and pruning of 50 to 80 percent. The area of smallholder rubber is 3,120 thousand hectares and oil palm is 1,222 thousand hectares that commonly cultivated without legume cover crops. The area of plantation rubber is 548 thousand ha and oil palm is 2,690 thousand hectares with estimate legume cover crops around 90% during establishment period. All areas of vanilla use legume tree as pole and shading. Black pepper could be planted on wood pole or tree pole. At least Lampung black pepper is mainly planted on legume tree with the total area of 63.808 hectares (Evizal, 2000).

Several methods are used to estimate fixation rate, including acetylene reduction assay, the N difference method, the N solute method, isotope dilution techniques, and the natural ^{15}N abundance method. Mafongoya *et al.* (2004) stated that there is no single correct way of measuring N_2 fixation. Some had been reported, that forage cover crops can derived 70-90% of their N supply, while thee legumes can

derive between 14-100% of their N supply from N_2 fixation. Estimated value of legume nodulating bacteria (LNB) in plantation could be based on the biomass produced by the legumes per year in total area of plantation. It is recognized that not all of nitrogen in the biomass being synthesized by LNB. Nitrogen could also be derived from N fixation by other soil biota and soil organic matter. Some studies have estimated N fixation rate of some trees and cover crop legumes. This approach could be debatable but it might be suggested as a rapid technique of economic valuation.

6.3 Legume Cover Crops (LCC)

In Indonesia, plantations of rubber and oil palm involve legume cover crops (LCC) as a standard of intensive culture. Planting LCC on rubber and oil palm is common for large-scale plantation, but not for smallholders because it requires extra labor and capital costs for planting and maintenance. LCC is recommended to be planted in plantation because of it improves soil fertility and plant productivity by: (a) minimizing soil erosion, (b) inhibiting growth of weed, (c) increasing soil fertility through nitrogen fixation by legume nodulated bacteria (LNB), litter production, and improving soil structure, (d) maintaining micro-climate (Erwiyono and Soekodarmodjo, 1989; Siregar, 1984).

Soon after land clearing, land has to be planted with LCC either prior or after planting the main crops (rubber or oil palm). Otherwise land will be covered by weeds that need to be controlled. LCC is planted in a row, and it will fully cover the land in 3-4 months by proper maintenance of fertilizing and weeding. Planting LCC would constitute extra expenditures, but once the land has been fully covered, the LCC will be alive for 5-6 years. During that period, the expense for weed control will decrease significantly. As the tree has covered and made full shading, LCC will be gradually died and subsequently changed by shade tolerant weed, but the weed growth will be not intensive due to low light condition.

Legume cover crops is some species of *Papilionaceae* with special growth habit and has many desirable characteristics such as: (a) perennial plant, (b) creeping on the ground, shoot branching, nodes rooting, (c) fast growing that cover the ground fast and produce high biomass, (d) tolerant to drought and shade, (e) high competition to weed. No single species of LCC however has that ideal growth habit. Hence 2-3 species of LCC are recommended to be planted together in the same field. Growth habit of twinning and climbing is helpful for competing and suppressing weed growth, but LCC needs to be maintained by hoeing around the main plant. Legumes that have spines are not recommended because harmful for workers.

Table 6.1 Species of LCC Commonly Grown in Plantation

No	Species	Family	Characteristics
1	*Calopogonium caeruleum*	*Papilionaceae*	Drought-shade tolerant
2	*Calopogonium muconoides*	*Papilionaceae*	Fast growing
3	*Centrosema pubescens*	*Papilionaceae*	Drought tolerant
4	*Centrosema plumieri*	*Papilionaceae*	Drought tolerant
5	*Pueraria phaseoloides*	*Papilionaceae*	Drought tolerant
6	*Pueraria thunbergiana*	*Papilionaceae*	Susceptible to shade
7	*Psophocarpus palustris*	*Papilionaceae*	Slow start of growth

Source: Adapted from Ditjen Perkebunan (1983).

Species of LCC commonly planted in Indonesia plantation are listed in Table 1. *Calopogonium caeruleum* shows a good growth habit, but produces less seed hence it should be propagated by cutting. Many species of creeping legumes are potential as LCC as listed in Table 2. Some

produce edible pods and leaves that might be suitable for smallholder but unsuitable for plantation. *Arachis pintoi* has been introduced to Indonesia since 1996 and cultivated as cover crop, landscape flower, and fodder. As cover crop, so far *Arachis pintoi* has not been adopted well by planters, although it exhibits medium growth and biomass production, not twinning the main plant, can stand pruning, and is drought tolerant (Evizal, 2003).

Table 6.2 Species of LCC Potentially Grown for Plantation

No	Species of LCC	Family	Characteristics
1	*Arachis pintoi*	*Papilionaceae*	Non twinning
2	*Psopocarpus tetragonolobus*	*Papilionaceae*	Edible, medium growth
3	*Psopocarpus scadens*	*Papilionaceae*	Medium growth
4	*Mucuna pruriens*	*Papilionaceae*	Edible, drought sensitive
5	*Mucuna cochinchinensis*	*Papilionaceae*	Fast growth
6	*Mimosa invisa*	*Mimosaseae*	Thorny, much root nodule
7	*Lablab purpureus*	*Papilionaceae*	Edible, drought tolerant
8	*Phaseolus lunatus*	*Papilionaceae*	Edible, annual-perennial

Source: Adapted from National Res. Council (1984), Van der Maesen and Somaatmadja (1993)

6.4 Legume Shade Trees

Legume shade trees consist of bush legume for temporary shading and tree legume for permanent shading. At the beginning establishment of certain industrial commodity such as cacao and clove, bush legumes are planted in rows to provide temporary shading for 1-2 years. When cacao and clove has been well grown, and need full sunshine, the temporary shading is pruned and cleared.

Temporary shade legumes are of *Papilionaceae* which have bush characteristics and fast growing. Bushes legumes provide shading and green manure that increases growth of the main plant. This type of legume is well adopted in large-scale plantation but not in smallholder. Smallholder farmers generally choose edible plants such banana as temporary shading. The magnitude of shading in cocoa plantation is fully shade all-year long from the young cocoa period (shaded with mixed shrub and young tree legume) up to mature cocoa period (shaded with tree legume). Temporary shade legume will die when cocoa and tree are tall enough and shading the ground fully.

Table 6.3 Species of Bush Legume for Temporary Shading

No	Bush legume	Family	Characteristics
1	*M. macrophylla*	*Papilionaceae*	Shading, manure
2	*Cajanus cajan*	*Papilionaceae*	Shading, edible pod
3	*C. usaramoensis*	*Papilionaceae*	Shading, manure
4	*Crotalaria juncea*	*Papilionaceae*	Shading, manure
5	*C. anagyroides*	*Papilionaceae*	Shading, manure
6	*C. zanzabarica*	*Papilionaceae*	Shading, manure
7	*Crotalaria alata*	*Papilionaceae*	Shading, manure
8	*D. gyroides*	*Papilionaceae*	Shading, manure
9	*D. stipulaceum*	*Papilionaceae*	Shading, manure
10	*D. adscendens*	*Papilionaceae*	Shading, manure
11	*Tephrosia vogelii*	*Papilionaceae*	Shading, manure
12	*Tephrosia maxima*	*Papilionaceae*	Shading, manure
13	*Tephrosia candida*	*Papilionaceae*	Shading, manure
14	*T. noctiflora*	*Papilionaceae*	Shading, manure
15	*I. hendecaphylla*	*Papilionaceae*	Green manure
16	*Indigofera hursuta*	*Papilionaceae*	Green manure

Source: Adapted from Sutarno and Atmowidjojo (2000), Van der Maesen and Somaatmadja (1993)

The use of bush legume for temporary shading is very common in both smallholder farmers and large scale plantation of coffee, cacao, and tea. In a large-scale plantation, shade tree sometimes is not used extensively because the monoculture practices and high rate of fertilizer

application are more preferred. Therefore, smallholder farmers using low level of fertilizer application is strongly recommended to plant legume shade tree. Shade tree legumes are able to increase soil fertility and maintain the level of productivity. Without shade tree, coffee and cocoa will commonly exhibit yellow leave and retarded growth. Vanilla is very tolerant of shading because it requires a pole or tree to climb. Without shading, vanilla will grow slow and die. Black pepper is able to grow well in full sunlight, but in Lampung the farmers grow pepper extensively on a pole tree.

Table 6.4 Species of Tree Legume for Shading and Pole

No	Species	Family	Growth	Shade
1	*G. sepium*	*Papilionaceae*	Fast	Hard
2	*E. indica*	*Papilionaceae*	Medium	Medium
3	*E. sububrams*	*Papilionaceae*	Medium	Medium
4	*E. variegata*	*Papilionaceae*	Medium	Medium
5	*E. poeppigiana*	*Papilionaceae*	Medium	Medium
6	*E. fusca*	*Papilionaceae*	Medium	Medium
7	*L.glauca*	*Mimosaceae*	Medium	Light
8	*L.leucocephala*	*Mimosaceae*	Fast	Medium
9	*L.diversifolia*	*Mimosaceae*	Fast	Medium
10	*P. speciosa*	*Mimosaceae*	Medium	Light
11	*P. falcataria*	*Mimosaceae*	Fast	Hard
12	*S. punctata*	*Papilionaceae*	Medium	Medium
13	*S. grandiflora*	*Papilionaceae*	Medium	Medium
14	*C. calothyrsus*	*Mimosaceae*	Medium	Medium
15	*D. microphylla*	*Papilionaceae*	Medium	Medium
16	*S. saman*	*Mimosaceae*	Fast	Hard
17	*Albizia procera*	*Mimosaceae*	Fast	Hard
18	*C. spectabilis*	*Caesalpiniaceae*	Fast	Medium
19	*P.dasyrrachis**	*Caesalpiniaceae*	Medium	Hard

Source: Adapted from Simanungkalit (2004), Van Steenis (2002). *) do not form nodule

Legume tree has economic potentials for smallholder farmers and commonly practiced in Indonesia. In additions to control the micro-climate, legume shade tree has other important functions such as: (1) root will make nodule that

able to fixate nitrogen from air, (2) producing litter as green manure or organic matter, (3) roots act as safety net of applied fertilizer, (4) deep roots act as plant nutrient pump, and (5) suppressing weed growth.

6.5 Economic Value of N-Fixation in the LCC and LSC

Legume cover crops (LCC) would fully cover the ground of plantation in the period of 1-2 years, reducing gradually in the period of 7-8 years. It could be estimated that for 5 years of establishment, LCC covers the plantation of rubber and oil palm. Evizal (2001) calculated that around 96-97 percent land would be effectively covered by LCC or intercrops. In case of mixed LCC of *Pueraria phaseoloides* and *Calopogonium caeruleum*, a hectare of those LCC could produce biomass that approximately supplying 133 kg nitrogen in a year into the soil (Siregar, 1984). It is estimated that about 60 percent nitrogen within the biomass of LCC are produced through N-fixating process by the LCC (legume nodulated bacteria (Mangoensoekarjo and Semangun, 2003).

The following assumptions are also used: (1) 90 percent of private and state owned plantation of rubber and oil palm planting LCC, (2) replanting period were 25 years, (3) replanting rate was 4 percent a year. Based on the above assumptions, it could be estimated that the value of N fixation by LNB of LCC in Indonesia plantation per year was equal to 99,233 ton urea. The use of urea was assumed at a recommended level for about 59,000 hectare of young oil palm (60 percent of existing area) and 173,000 hectare of young rubber (36 percent of existing area) every year. However, the recommended dosage of fertilizer for young oil palm plantation with LCC is lower than those for non LCC plantation, e.g. reducing about 20 percent of ZA fertilizer, 23 percent of Rock Phosphate, 11 percent of KCl, and 10 percent of Kieserit fertilizers. This is because LCC biomass could serve not only as source of nitrogen but also another macro and micro-elements.

Table 6.5 Estimated Value of N fixation by LCC in Indonesia

	Rubber plantation	**Oil palm plantation**
Total area of private and state owned plantation*)	548,000 ha	2,690,400 ha
Plantation area of planting LCC (90%)	493,200 ha	2,421,360 ha
LCC area of 1-5 year establishment period (20%)	98,640 ha	484,272 ha
Effective area of LCC (96%)	94,694 ha	464,901 ha
N of biomass produced (133 kg ha^{-1} $year^{-1}$)	12,594 ton	61,832 ton
N fixation (60%) ($year^{-1}$)	7,556 ton	37,099 ton
N fixation equal to urea (45%N)($year^{-1}$)	16,791 ton	82,442 ton
Total Value ($year^{-1}$)	99,233 ton	

*) Based on BPS (2003)

Shade legume trees commonly planted in coffee garden are *Erythrina* and *Gliricidae*, in cocoa are *Leucaena* and *Gliricidae*, in black pepper are *Erythrina* and *Gliricidae*, while in Vanilla are *Leucaena* and *Gliricidae*. *Erythrina* tree produces N biomass 108 kg per hectare per year, *Leucaena* produces 180 kg, and *Gliricidae* produces 232 kg (Hairiah *et al.*, 2000). Assuming the intensity of coverage and pruning is 65 percent, estimation of N fixation rate by that legume tree is 57 percent, and the estimated value of N fixation by LNB of shade tree in Indonesia is shown in Table 6.6. Therefore, the total amount of N fixation through legume shade tree is equivalent to 170,187 ton of urea.

Table 6.6 Estimated Value of N fixation by Bush Legume and Legume Shade Tree in Four Main Estate Crops in Indonesia

	Coffee	Cacao	Pepper	Vanilla
Plantation area (ha)*	1,389,900	828,600	204,068	12,100
Plantation area with shade tree (ha)	694,950	414,300	63,808	12,100
Pruning intensity (%)	65%	55%	75%	100%
N biomass produced by shade tree (kg ha^{-1} $year^{-1}$)	170	206	170	206
Total N biomass production (ton $year^{-1}$)	76,792	46,940	8,135	2,493
N fixation (57%) per year (ton)	43,771	26,756	4,637	1,421
N fixation equal to urea (45%N)	97,269 ton	59,456 ton	10,304 ton	3,158 ton
Total value ($year^{-1}$)	170,187 ton			

*) Based on BPS (2003)

The estimated value of N fixation by bush legume and legume shade of coffee (97,269 ton urea) is equal to recommended fertilize 97,269 hectares mature coffee or 14 percent of existing shaded coffee area; by shade tree of cacao (59,456 ton urea) is equal to fertilize 118,912 hectares mature cacao or 29 percent existing shaded cacao; by shade tree of black pepper (10,304 ton urea) was equal to fertilize 5,888 ha of mature black pepper or 9 percent of existing shaded black pepper. Therefore, the total estimated value of N-fixation from LCC, bush legume and legume shade of

important plantation crops in Indonesia is equal to 269,420 tons urea per year.

6.6 Summarized Conclusion

There are at least 15 species of legume cover crops (LCC) and 16 species of bush legume for temporary shade, and 19 species of legume shade tree have been used as auxiliary plants. Estimated value of N-fixation by the legume nodulating bacteria (LNB) in LCC, bush legume and legume shade tree could be based on the biomass produced by the legumes per year in total area of the plantation. Using assumptions based on previous research on biomass production, the total value of LNB in Indonesia plantation is about 269,420 ton urea equivalent per year.