論　文

Yields of cash crops in a planted teak forest under agroforestry management in Madiun, East Java, Indonesia

Ris Hadi Purwanto*, Kanji Ito* and Seiichi Oohata*

インドネシア，東ジャワ，マディウンにおけるアグロフォレストリー・チーク林の畑作物収量

リス　ハディ　プルワント*・伊藤幹二*・大畠誠一*

ジャワ島東部のマディウンのアグロフォレストリー・システムによって管理されている若いチーク人工林では，林内で生産される農作物等のための耕耘，除草，施肥等の土壌管理効果によって，チークの高い生産力が維持されていることを認めた．そこで，本チーク人工林内における畑作物の収量を調査し，チーク人工林およびその管理が畑作物の収量に及ぼす影響について考察した．ここでは，この地域のチーク・アグロフォレストリーの農民にとって，直接的な収入となるキャッサバ（*Manihot esculenta* Crantz），トウモロコシ（*Zea mays* L.），陸稲（*Oryza sativa* L.），落花生（*Arachis hypogaea* L.），大豆（*Glycine max* (L) Merr）の収穫量について調査した．収量調査は，9 mまたは24m幅の樹木間列状植栽の行なわれているキャッサバ10㎡，トウモロコシ4㎡，陸稲，落花生，大豆1㎡を，ランダムに5個所選んで行った．この結果，ヘクタール当りの平均収量はキャッサバが16.1 ton ha^{-1}，トウモロコシ3.2 ton ha^{-1}，陸稲3.4 ton ha^{-1}，落花生1.8 ton ha^{-1}，大豆1.3 ton ha^{-1}であった．このチーク林間の畑作物の平均収量は，陸稲を除いてインドネシアの全国平均のそれを大きく上回った．また，これは他の熱帯アジアの一般耕地における平均収量と比較しても高かった．このチーク人工林における畑作収量の高さは，東ジャワの気候条件の影響があるにしても、集約的な土壌管理に加え，チーク・リターによる土壌保全や養分供給などの要因にもよると推察される．

キーワード：アグロフォレストリー，チーク人工林，換金作物収量，熱帯多雨地域，東ジャワ

Yields were determined in cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), rice (*Oryza sativa* L.), groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L.) Merr.) which were grown in a planted teak forest under agroforestry management in a moist tropical region in the Madiun Forest District, East Java, Indonesia. The research was carried out from October 2000 to July 2001. The average yields were 16.1, 3.2, 3.4, 1.8 and 1.3 ton ha^{-1} in the cassava, maize, rice, groundnut and soybean, respectively. Yields of cassava, maize, groundnut and soybean in the Madiun Forest District were higher than those of average yields in ordinary fields of Indonesia and also in most of other tropical countries despite of growing on the rainfall conditions. These high yields of the crops are considered to be partly because of humid and high temperature climate conditions in East Java. However, the high yield of crops planting under agroforestry seemed more influenced by the teak plantation management in East Java including an application of intensive cultural practices such as soil management (tillage in land preparation and weeding), fertilization with chemicals or manure and leaf litter supply from the teak forests.

Key words: Agroforestry, planted teak forest, yields of cash crops, moist tropical region, East Java

1. Introduction

As in most of Java regions, the major teak forest problems in East Java are forest land encroachment, shifting cultivation, illegal log poaching, illegal firewood and charcoal wood collection[18]. The devastation of the forests is primarily a consequence of expanding human population and their needs for arable lands to feed themselves and for fuel-wood, rather than a consequence of industrial forest exploitation. The increasing labor force cannot be absorbed by the available opportunities for employment in the manufacturing and trade sector, so the rural population has to depend to a large extent on agricultural and teak forest lands to support themselves. These landless people depend almost exclusively on the forest for their income[17]. To combine the use of certain piece of land for forestry,

* 京都大学大学院農学研究科　森林科学専攻
* Division of Forest and Biomaterials Science, Graduate School of Agriculture, Kyoto University

agriculture, and/or livestock at the same period of time. Perhutani (the State Forest Enterprise in Indonesia) is now aimed to increase upland agricultural and forestry production through agroforestry management[22]. Agroforestry is land use system (a) in which woody perennials and herbaceous crops are grown together in mixtures, zonally and/or sequentially, with or without cattle, and (b) which provides greater benefits for the land use than agriculture or forestry alone, including one or more of the following: sustained soil fertility, soil conservation, increased yield, reduced risk of crop failure, easy of management, pest and disease control, and/or greater fulfillment of the socio-economic needs of the local population[2]. In the agroforestry, landless farmers get the opportunity to plant food crops such as cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), rice (*Oryza sativa* L.), groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L.) Merr.) on the forest land, subsidies to buy agricultural devices, fees for land preparation and fertilizers (both chemical and manure) in the newly established teak plantations[22].

The management of planted forests under agroforestry in Indonesia has a long tradition. Consequently, there is an extensive body of empirical knowledge on the use and management of the trees and associated crops. The productivity of teak plantations under agroforestry management in East Java has been recorded[16]. The yields of cash crops which grown on rice fields is relatively well documented[5], but more the crops studies under agroforestry management should be undertaken. Though teak forests have been raised on a large scale under agroforestry management by the State Forest Enterprise, a database on aspects of yields of cash crops is lacking. This report presents the results of a study on the yields of cash crops in a planted teak forest under agroforestry management.

2. Material and methods

2.1. Description of study area

The study area is located at the eastern foot of Mt. Lawu (7° 30′ S and 112° 30′ E) in East Java, Indonesia and is managed by Madiun Forest District, a State Forest Enterprise under the control of Perhutani in Java. The Madiun district is a regency city in East Java Province covering an area of ca. 1,154 km^2 or 2% of the total land in East Java (47,922 km^2). At present, food crops such as rice, cassava, groundnut, maize and soybean are not self-sufficient in the East Java, so a large area of forests are planted various food crops under agroforestry management such as in the Madiun Forest District. Most of food crops in the Madiun Forest District are grown mainly under rainfall conditions, which is solely dependent on rainwater and does not receive any additional water at any step of cultivation through irrigation[21]. Agricultural crops are planted every year throughout the entire rainy season (October-June). Rice, maize, groundnut and soybean are usually grown two times a year in the Madiun Forest District: the 1st crop (planted in November and harvested in February) and the 2nd crop (planted in March and harvested in June), while cassava is grown one time a year (planted in October/November and harvested in July/August). Various aged teak forests in the Madiun Forest District grow on volcanic soil from 50m to 600m in altitude.

Air temperature is relatively stable throughout the year with mean annual temperatures of 28.8℃, and the mean annual precipitation from 2000 to 2001 was 1865 mm. The monthly mean temperature and precipitation in 2000 – 2001 at the research site is consistent with typical monsoon climate with short dry season (July to September) as shown in the Fig. 1. On Whitmore's map of rainfall types for the tropical

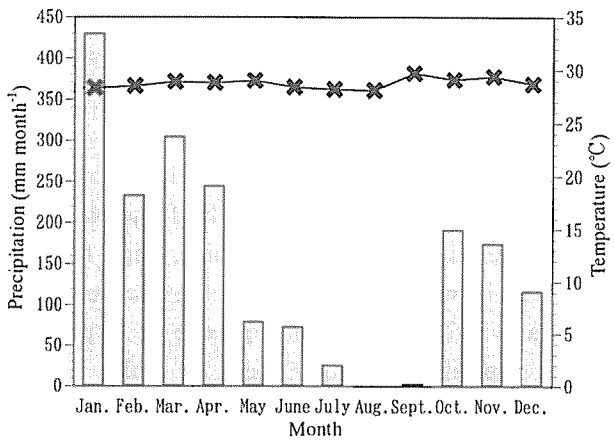

Fig. 1. Monthly means of precipitation and temperature in 2000-2001 in Madiun Forest District. Cross, monthly mean temperature; histogram, monthly precipitation.

Far East, the area is classified into types C and D or seasonal type[24].

The geological structure in most of the area is volcanic, the soil type belongs to the red-brownish latosol, and the topography is gently undulating and slightly rocky[14].

2.2. Plant materials

The research materials were cash crops (cassava, maize, rice, groundnut and soybean) in a teak forest plantation under agroforestry management, which extended over an area ca. 1000 ha. The crops were cultivated on 9 m and/or 24 m wide alleys of hedge between teak rows. Teak seeds were directly sown on the site by spacing of 3 × 1 m. Therefore, this is an agroforestry system in which crops fields and forest land are separated distinctly. The rice, maize, groundnut and soybean were planted in March 2001 and harvested in June 2001, while the cassava was planted in October 2000 and harvested in July 2001. Cassava and rice were grown on 9 m and 24 m to groundnut and soybean on 9 m and maize on 24 m alleys. Intensive cultural practices such as soil management and fertilization were performed during the crops planting. Cow dung, poultry manure and/or decomposed rice as manure fertilizers were applied to cassava, maize, groundnut and soybean only as basal dressing, while urea was applied to rice. *Leguminous* species (*Leucaena glauca*) for the purposes of supplying fodder and green manure were grown by line planting between teak rows in the initial stage. Stem of *Leucaena glauca* trees were cut about to 10 cm above ground level at a half-year-old after sowing as usually done to cover the land surface.

2.3. Estimation of crop yields

To estimate crop yields which grown on four different 1 to 9-year-old teak forest plantations under agroforestry, twenty quadrats of 1 × 10 m and 1 × 1 m, five quadrats of 2 × 2 m and ten quadrats of plots of 1 × 1 m were randomly placed in the cropland of cassava and rice, maize and soybean and groundnut, respectively (Table 1). Measurement of yields was carried out when harvesting in the end of growing season (June 2001) for rice, maize, groundnut and soybean and in dry season (July 2001) for cassava. The sub-samples for determining dry weights were taken from tubers of cassava, grains of rice, maize, groundnut and soybean, and were dried out at 60℃ until a constant weight was reached.

3. Results and discussion

Table 2 shows the average food crops yield in cassava, maize, rice, groundnut and soybean grown on a planted teak forest under agroforestry management in Madiun, East Java. For the purpose of comparison, average yields of ordinary fields in Indonesia and the most of other tropical countries based on the FAO data is also given in the table.

Table 1. Description of the sampled cash crops on the teak plantations

Cash crops	Date planting	Date harvesting	Alley width (m)	Plot size (m^2)	Number of quadrats	Teak stand age (years)
Cassava (*Manihot esculenta* Crantz)	October 2000	July 2001	9	1×10	5	1
			24	1×10	5	9
Maize (*Zea mays* L.)	March 2001	June 2001	24	2×2	5	8
Rice (*Oryza sativa* L.)	March 2001	June 2001	9	1×1	5	3
			24	1×1	5	8
Groundnut (*Arachis hypogaea* L.)	March 2001	June 2001	9	1×1	5	3
Soybean (*Glycine max* (L.) Merr.)	March 2001	June 2001	9	1×1	5	3
Total	-	-		-	35	-

Table 2. Comparison of yields of cash crops in Madiun, East Java (mean ± S.D.) and most of other tropical countries in 2001

No.	Country	Average of cash crop yields (ton ha^{-1})				
		Cassava (tuber)	Maize (grain)	Rice (grain)	Groundnut (grain)	Soybean (grain)
1.	Madiun, East Java	16.1±3.6	3.2±0.5	3.4±1.1	1.8±0.4	1.3±0.3
2.	Indonesia	12.9	2.8	4.4	1.5	1.2
3.	Cambodia	10.5	2.8	2.1	0.8	0.9
4.	Laos	13.7	2.6	3.1	1.4	0.9
5.	Malaysia	10.0	3.0	3.1	3.8	-*
6.	Myanmar	10.7	2.1	3.5	1.2	1.0
7.	Philippines	7.6	1.8	3.2	1.0	1.2
8.	Thailand	18.0	3.6	2.7	1.5	1.4
9.	Vietnam	10.6	2.9	4.3	1.5	1.3
10.	India	25.6	2.0	3.1	1.1	0.9
	Average	13.6	2.7	3.3	1.6	1.1

1 Data from the present study (2001)
2-10 Data from FAO (2001)
* Data is not available

Average yields of soybean, maize, rice, groundnut and cassava in the Madiun Forest District were higher than those of average yields in most of tropical countries. There were remarkable inter-country differences in yield levels. The current status of each crop in the research is summarized in the following paragraphs.

3.1. Cassava (*Manihot esculenta* Crantz)

In Madiun Forest District, yields of cassava were slightly higher of those in Indonesian averaged yield (Table 2). It is well known that in the tropical countries cassava can be grown on marginal land, which is not suitable for other food crops. However, the high yield seemed more influenced by the teak plantation management in East Java including an application of intensive cultural practices such as soil work (tillage in land preparation and weeding), fertilization with manure, and leaf litter supply from the teak forest. Table 2 shows the value was comparable with those in Thailand and was much lower compared with those in India. Cassava yields ranged from 10 to 11 ton ha^{-1} in Cambodia, Malaysia, Myanmar and Vietnam to about 12 to 13 ton ha^{-1} in Indonesia and Laos, and the lowest yield was less than 8 ton ha^{-1} in Philippines. The difference of averaged yields outside Indonesia may be related to climate conditions. Cassava does well in a warm moist climate where mean temperatures range from 25-29℃, and annual rainfall reaches 1000-2000 mm. It performs poorly under cold climates and temperatures below 10℃, where growth of the plant is arrested[3]. The study area in Madiun Forest District, East Java is included in climate condition, suitable for growing cassava. Indonesia is one of most important cassava producing countries in the world[9], and cassava is now still used as a traditional staple food in East Java.

3.2. Maize (*Zea mays* L.)

Maize is an important crop as staple food crop next to cassava and rice in Indonesia. In Madiun East Java, the yields of maize were higher about to six-fifths of those in average of most tropical countries. The yields were comparable with those in Thailand and Malaysia and were fairly higher compared with those in average of other tropical countries. As the cassava

yields, the lowest maize yield was less than 2 ton ha^{-1} in Philippines. Maize is not suited to semi-arid or equatorial climates. For adequate growth and development the crop requires an average daily temperature of at least 20℃. In the tropics it does best with 600-900 mm of rain during the growing season[23]. It is, therefore, the highest maize yield is not generally from semi-arid or equatorial climates countries[5].

4.3. Rice (*Oryza sativa* L.)

Table 2 shows the rice yields ranged from 2 to 4 ton ha^{-1} with the highest yield was over 4 ton ha^{-1} of lowland rice in Indonesia and Vietnam. The lowest yield was less than 3 ton ha^{-1} in Cambodia. Yields of rice in Madiun Forest District were comparable with those in average of the most of other tropical countries about to over 3 ton ha-1. Most of the rice areas of the world depend on rain for irrigation, particularly true of the Asian countries outside Japan and of the tropics and underdeveloped regions in general[25]. Where rain is used for irrigation, the onset of the wet season is a critical factor. It is, therefore, an upland rice in Madiun Forest District is planted throughout only the entire rainy season (October-June).

3.4. Groundnut (*Arachis hypogaea* L.)

In Madiun Forest District, yields of groundnut were higher of those in average of the most of tropical countries. The value was comparable with those in Thailand, Indonesia and Vietnam and was much lower compared with those in Malaysia. Table 2 shows groundnut yield ranged from 1 to 2 ton ha^{-1} in India, Myanmar, Laos, Vietnam, Thailand, Indonesian averaged yield and East Java. Malaysia is the highest yield to about 4 ton ha^{-1}, and the lowest yield was less than 1 ton ha^{-1} in Cambodia. The high yields of groundnut in Madiun, East Java compared with those in average of other tropical countries was expected using intensive farming method under agroforestry management. Groundnut is mainly grown in Asia under rainfed conditions[11]. Groundnut is also grown under high input conditions, for instance in the southeastern part of the United States of America and in Argentina, where yields of over 4 ton ha^{-1} are obtained[5,25]. In Indonesia, groundnut is largely used for human consumption such as roasted snacks or peanut butter and desserts[1].

3.5. Soybean (*Glycine max* (L.) Merr.)

In Madiun East Java, the soybean yields was slightly higher than those of tropical countries. Table 2 shows soybeans yields are over 1 ton ha^{-1} in the most of tropical countries, except in Cambodia, Laos, and India. Soybean has similar ecological requirements to maize[3]. In a humid subtropical climate is most favorable for soybean crops. Although 24-25℃ is preferred for optimal growth, the 20-25℃ range is still excellent for the growth of the plant. Rainfall required for a good yield in warmer areas is 500-700 mm[3]. It is, therefore, the highest soybean yield is not generally from semi-arid or equatorial climates countries[5,23].

4.6. Food crops planted under hedgerow intercropping

Hedgerow intercropping or alley cropping is an agroforestry technology that is being explored as one of the land use options in the tropics[19]. It is a land management practice in which crops are grown in the interspaces between rows of planted woody shrub or tree species, usually legumes, and in which the woody species are periodically pruned during the cropping season. Alley cropping retains some of the main advantages of shifting cultivation, viz., regenerating soil fertility, providing green manure, firewood and stakes, and suppressing weeds[12]. In Madiun Forest District, the species currently under study at a lowland humid conditions include teak (*Tectona grandis*) and food crops such as cassava, rice, maize, groundnut and soybean which grown on 9 and/or 24 m-alley width of teak hedgerows. Some of available information on the comparative effects of alley width is given in Table 3. The table shows yields of intercropped cassava at 9 m is comparable with those at 24 m-alley widths ($P>0.05$). On the other hand, the yields of intercropped rice was about to half at 9 m, and was significantly lower than that of 24 m-alley widths ($P<0.01$). It is well known that in the tropical countries cassava is able to grow on less fertile soil and requires less exacting environmental conditions compared to rice. The rice plant is a typical annual crop, which is a short period growth about 3-4 months from sowing and the flowering time is very sensitive to shading. Similar trend, in other researches were

Table 3. Comparison of yields (mean ± S.D) in narrow and wide alleys on the teak plantations

Agricultural crops	Yields (ton ha^{-1}) on	
	9 m-alley widths	24 m-alley widths
Cassava	15.7±4.7	16.5±2.6^{ns}
Rice	2.5±0.9	4.2±0.5**

Significance level: ns, not significant; ** P<0.01 by *t*-test

reported that in yields of other annual crops, cowpea and maize which grown on a planted *Acioa barterii* and *Alchornea cordifolia* forests at 4 and 2 m-alley width[10] to maize in *Gliricidia sepium* and *Tephrosia candida* forests at 6 and 2 m-alley width[8] and to cassava in *Leucaena leucocephala* forests at 3 and 1 m-alley width[4].

Yields of cassava, maize, rice, groundnut and soybean in the Madiun Forest District were higher than those of average yields in the most of tropical countries despite of growing on the rainfed conditions. High yield of the food crops is considered to be partly because of humid and warm climate conditions in East Java. However, the high yield of crops planting under agroforestry seemed more influenced by the teak plantation management in East Java including an application of intensive cultural practices such as soil management (tillage in land preparation and weeding), fertilization with chemicals or manure and leaf litter supply from the teak forests.

Soil management in site preparation is now receiving increased attention as a means of improving root zone soil water supply. This may be accomplished through removal of competing vegetation, increasing soil water storage or encouraging more extensive seedling root development[6]. Pattern of leaf litter fall in teak planted under agroforestry seemed to have a positive influence on sustaining the crops planting by the soil conservation. Field observation in leaf litter fall of teak planted under agroforestry management for a year showed the average of leaf litter fall was 5.13 ton ha^{-1}, almost the same as that of the average measured in over twenty tropical forests, at 5.50 ton ha^{-1} [20]. The mean seasonal pattern of leaf litter fall in teak planted under agroforestry management in the Madiun Forest District is shown in Fig. 2. The peak leaf-fall period was during the months of May-June when it is the end of the growing season in the planted area. In forest ecosystems, litter fall is an important flux of carbon

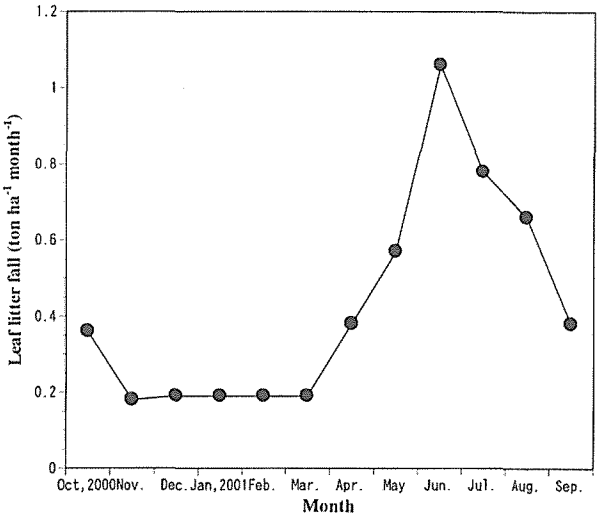

Fig. 2. Pattern of leaf litter fall in teak planted under agroforestry management in the Madiun Forest District, East Java from October 2000 to September 2001.

and nutrients into the decomposer system in soil where nutrients are mineralized[26]. This continuous availability of nutrients is one of the major factors, which decides the site productivity[7]. Application of fertilizer both chemicals and manure is expected to increase rates of litter decomposition, resulting in faster rates of nutrient cycling[15]. *Leguminous* species (*Leucaena glauca*) was grown by line planting between teak rows in the initial stage is also useful in erosion control because of its permanence under natural stress conditions and ability to grow on steep slopes.

Some advantages of food crops planted under agroforestry management are increased productivity, improved space utilization and soil characteristics, reduced risk of crop failure and as well as the improved local incomes in developing countries, including Indonesia. The disadvantages, as seen in Javanese teak plantations, are increased competition between trees and crops and allelophathy effect of trees[13]. These will hopefully be overcome in time.

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