DUDUKUHAN TREE FARMING SYSTEMS IN WEST JAVA: HOW TO MOBILIZE THE SELF-INTEREST OF SMALLHOLDER FARMERS?

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Abstract

Dudukuhan are traditional tree farming systems in West Java, Indonesia. Dudukuhan can be divided into 4 types: 1) timber system, 2) mixed fruit-timber-banana-annual crops system, 3) mixed fruit-timber system, and 4) fallow system. Traditionally all types of dudukuhan are managed on an extractive basis, few inputs (quality germplasm, fertilizers, labor, etc) are allocated to these systems. This management approach is caused by: limited land tenure, small land size, off-farm employment opportunities, limited market access, and farmers' limited experience with intensive tree management. Depending on the socioeconomic conditions and market opportunities facing a farmer, the allocation of a specific piece of land may shift between the four types of dudukuhan. This transformation occurs gradually over a number of years and affects the tree biodiversity and total number of trees in the system. A desire for tree products, market opportunities and land tenure status are the key factors that influence farmers' decision concerning which type of dudukuhan to develop. Positive changes in these factors have a positive influence on tree biodiversity and tree density. Income generation is the primary factor influencing farmers' choice of tree species. Soil conservation is a secondary but important factor influencing both choices of dudukuhan and tree species. Farmers are interested in intensifying the management of their dudukuhans, but hesitate because they do not know where to focus their efforts. Experience indicates that farmers in Nanggung may be best served by transforming their traditional subsistence tree farming systems into semi-commercial enterprises that yield products to meet both home and market demand. Agriculture and forestry extension officer in district level, subdistrict government, NGOs and research institutes can facilitate this process by providing access to quality inputs, training and information. However, the driving force should be farmers' self-interest to improve their livelihoods.

A. Background

Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production that derives from the (potential) social, economic and environmental benefits for all land users (World Agroforestry Centre, 2004).

In Indonesia, most agroforestry systems are established through shifting cultivation, which complements relationships between trees and crops, and between forest and farming (Michon and de Foresta, 1995). The complementary relationship is that the natural forest may support livelihoods of local people and at the same time forest vegetation may gradually establish on farms (de Foresta *et al.*, 2000). Indonesia boasts a number of agroforestry models that established gradually with the integration of both biophysical and socioeconomic functions. Examples of these models include: the repong damar resin producing system in Krui, Lampung; the jungle rubber systems in Jambi and South Sumatera; the tembawang (fruit and timber products) system in West Kalimantan; the pelak system in Kerinci-Jambi, the durian gardens in Gunung Palung-West Kalimantan, the parak system in Maninjau-West Sumatera, and the talun-dudukuhan systems in West Java (de Foresta *et al.*, 2000).

Dudukuhan are traditional tree farming systems in West Java, Indonesia. Dudukuhan can be divided into 4 types: 1) timber system, 2) mixed fruit-timber-banana-annual crops system, 3) mixed fruit-timber system, and 4) fallow system. These systems are distinguished from homegardens (pekarangan) by location – away from the house – and a lower level of management. Traditionally all types of dudukuhan are managed on an extractive basis, few inputs (quality germplasm, fertilizers, labor, etc) are allocated to these systems. This management approach is caused by: limited land tenure, small land size, limited market access, and farmers' limited experience with intensive tree management. Limited management results in low system productivity and low farm income.

A study was conducted to characterize dudukuhans and evaluate their potential as a system for poverty reduction. Three key points were addressed: 1) tree diversity and dudukuhan profiles based on sample villages and dudukuhan types, 2) farmers' perceptions of the selection and uses of tree species on management of dudukuhan systems, and 3) identify and analyze ideas for empowering and mobilizing self-interest of farmers on enhancing productivity and profitability of dudukuhan systems. Results from the study were used by World Agroforestry Centre (ICRAF), Winrock International and the Indonesia Institute for Forest and Environment (RMI) to help farmers improve the productivity and market-orientation of their dudukuhan systems. This paper reports on key results of that study.

B. Methods

***Site*.** The study was conducted in Nanggung subdistrict located at longitude 106^o 27' 35" to 106^o 35' 26" and latitude 06^o 33' 25" to 06^o 45' 45". Nanggung subdistrict consists of 10 villages with an area of around 11,000 km^2 and elevation between 400 and 1800 m.a.s.l.. Nanggung has 74,211 inhabitants and 17,187 households. Average landholding per household is 0.3 ha of irrigated riceland and 0.5 ha of dudukuhan. Dudukuhan systems cover 16.7% of total area of the subdistrict. While 73.3% of the household heads consider themselves farmers, agriculture provides only 31.2% of household incomes. Trade (operating small shops), the service sector, gold mining, bentonite mining and plantation work are alternative sources of household income (Budidarsono *et al.*, 2004). The study was conducted in three sample villages that were purposively selected according to their location (upstream, mid-stream, and downstream). The villages selected are Cisarua, Curug Bitung, and Parakan Muncang.

***Tree Diversity and Dudukuhan Profiles*.** The tree diversity and profiles of dudukuhans were assessed through an inventory of 36 dudukuhans. Three of each dudukuhan type were inventoried in each of three villages. The Dynamic Sample Unit method developed by Sheil *et al*. (2002) was used to conduct the inventory. The method uses 40-m long transect lines to measure species richness, tree density, and tree basal area. The transect line is divided into 8 tree sampling units as depicted in Figure 1. Within each unit a maximum of 5 trees are measured. Trees must have a diameter at breast height (dbh[1]) greater than 10 cm. For each sampling unit, the following data were recorded: the number of trees, the species of trees, the dbh of each tree and distance of the fifth tree from the transect line (d1, d2, d3 … as depicted in Figure 1). The maximum distance for searching up to five stems is 20 m (d7). The maximum distance for searching in each cell before deciding it is 'empty', is 15 m (d6).

[1] Diameter breast height is a trees diameter a height of 1.3 meters above the ground.

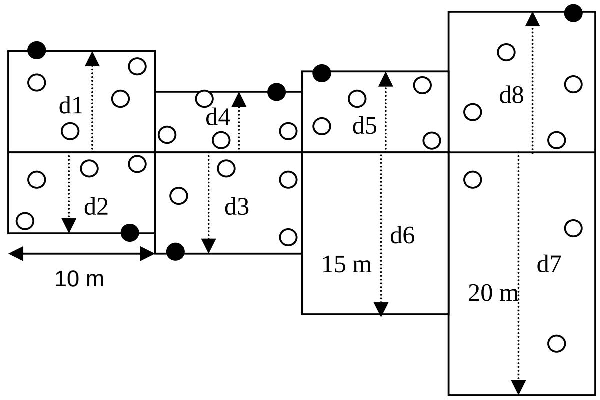

Figure 1. Tree sample units along 40 m of transect line

Farmers' Perceptions Regarding Tree Selection and Uses. Participatory Rural Appraisal (PRA) methods, namely group discussions and individual interviews, were used for collecting information about farmers' perceptions regarding tree selection and use. Farmers' perceptions on tree selection were compiled under three main variables: i) tree biophysics, ii) landscapes and climate, iii) socioeconomic. Fourteen variables were used to identify farmers' perceptions regarding tree use: (a) leaves' biomass, (b) canopy shading, (c) root characteristics, (d) fast growth and fruiting, (e) tree use value, (f) pests-diseases, (g) dudukuhan size, (h) slope angle (in degrees), (i) soil type and fertility, (j) elevation, (k) weather and rainfall, (l) marketing opportunities, (m) land tenure statue, and (n) government policy. Farmers' perceptions on tree use were explained by eight variables including: (a) foods, (b) income, (c) fire wood, (d) construction, (e) fodder, (f) medicine, (g) erosion control, and (h) child education.

Management of Dudukuhans**.** Dudukuhan management - including inputs, outputs and financial returns - were documented as part the farm and household economic study of dudukuhan owners in Budidarsono *et al*. (2004). Thirty five households were purposively selected to be interviewed in each of the sample villages mentioned above.

C. Results

Tree Diversity and Dudukuhan Profiles**.** Measurements were made on a total of 36 dudukuhans. Dudukuhan sizes reported by the landowners varied between 0.054 and 0.419 ha (Budidarsono *et al.*, 2004). A total of 51 tree species (excluded banana plants) were identified as components of dudukuhan systems. These include 25 fruit species and 26 timber species. The Shannon-Weiner Index (H') (Smith, 1990) was used to describe the tree diversity in the dudukuhan systems. Shannon-Weiner Index for each sample village is as follows: Cisarua (1.02), Curug Bitung (0.97), and Parakan Muncang (1.19). Statistically, there is no difference between villages in tree diversity (Shannon-Weiner Index). A high number of trees of afrika timber (*Maesopsis eminii Engl*.) (34.6%) compared to other tree species causes the tree diversity value for Curug Bitung village to be lower than the values for the other sample villages, although the number of tree species in Curug Bitung village was higher than either Cisarua or Parakan Muncang villages. Table 1 shows that the number of fruit tree species was higher than timber tree species in all sampled villages. The numbers of fruit tree species in Parakan Muncang and Curug Bitung villages were higher than in Cisarua village. But the numbers of timber tree species in Curug Bitung and Cisarua villages were higher than in Parakan Muncang village.

Table 1. Tree species composition based on samples villages in the Nanggung subdistrict in West Java.

Local Name	Botanical Name	Tree Number (per Ha)			Percentage (%)		
		Cisarua	Curug Bitung	Parakan Muncang	Cisarua	Curug Bitung	Parakan Muncang
Fruit Products							
Cempedak	*Artocarpus integer (Thunb.) Merr*	0	0	1	0.0	0.1	0.2
Cengkeh	*Eugenia aromatica O.K.*	2	4	10	0.5	0.7	1.5
Duku	*Lansium domesticum Corr.*	6	7	2	1.5	1.3	0.3
Durian	*Durio zibethinus Murr.*	3	6	15	0.7	1.1	2.2
Gandaria	*Bouea macrophylla Griff.*	0	0	1	0.0	0.0	0.2
Jambu air	*Syzygium aqueum (Burm.f.) Alston*	0	1	0	0.0	0.2	0.0
Jengkol	*Archidendron pauciflorum (Benth.) Nielsen*	8	21	31	2.0	3.7	4.6
Kapuk randu	*Ceiba pentandra (L.) Gaertn.*	1	2	5	0.1	0.3	0.8
Kecapi	*Sandoricum koetjape (Burm.f.) Merr*	1	4	21	0.3	0.7	3.1
Keluih	*Artocarpus communis J.R. & G.Forster*	0	1	0	0.0	0.1	0.0
Kemang	*Mangifera caesia Jack ex Wall.*	11	2	10	2.8	0.3	1.5
Kemiri	*Aleurites moluccana (L.) Willd.*	3	0	0	0.8	0.0	0.0
Kepayang	*Pangium edule Reinw.*	1	4	0	0.3	0.7	0.0
Kupa gowok	*Eugenia polycephala Miq.*	7	4	3	1.8	0.7	0.4
Kweni	*Mangifera odorata Griff.*	4	5	18	1.0	0.8	2.7
Lamtoro	*Leucaena leucocephala (Lam.) de Wit*	1	0	0	0.2	0.0	0.0
Limus	*Mangifera foetida Lour.*	4	1	1	0.9	0.1	0.1
Mangga	*Mangifera indica L.*	0	0	5	0.0	0.0	0.8
Manggis	*Garcinia mangostana L.*	0	2	9	0.0	0.3	1.3
Melinjo	*Gnetum gnemon L.*	0	0	14	0.1	0.0	2.0
Menteng	*Baccaurea racemosa (Reinw.) Muell. Arg*	0	1	1	0.0	0.1	0.1
Nangka	*Artocarpus heterophyllus Lam.*	42	11	13	10.0	2.0	1.9
Pala	*Myristica fragrans Houtt.*	0	2	0	0.0	0.4	0.0
Petai	*Parkia speciosa Hassk.*	4	21	10	1.0	3.8	1.6
Pisang	*Musa sp.*	54	121	267	13.0	21.4	39.7
Rambutan	*Nephelium lappaceum L.*	6	9	39	1.4	1.7	5.8
Timber Products							
Afrika	*Maesopsis eminii Engl.*	121	195	48	29.2	34.6	7.1
Calik angin	*Macaranga tanarius*	1	0	0	0.2	0.0	0.0
Cangkalak	*Knema laurina (Blume) Warb.*	0	3	0	0.0	0.6	0.0
Jirak	*Symplocos ferruginea*	1	0	0	0.3	0.0	0.0
Kanyere	*Bridelia minutiflora Hook. f.*	0	1	0	0.0	0.1	0.0
Karet	*Hevea brasiliensis Muell. Arg.*	0	0	17	0.0	0.0	2.5
Kihiang	*Cassia javanica L.*	1	0	0	0.2	0.0	0.0
Kihujan	*Engelhardia spicata Lech. ex Bl.*	0	1	0	0.0	0.1	0.0
Kihuru	*Litsea noronhae*	4	0	0	1.0	0.0	0.0
Kikacang	*Maniltoa grandiflora Scheff.*	1	0	0	0.2	0.0	0.0
Kirinyuh	*Eupatorium inulifolium H.B.K.*	0	1	0	0.0	0.1	0.0
Kisampang	*Euodia latifolia DC.*	29	19	0	7.1	3.4	0.0
Meranti	*Shorea spp.*	0	3	0	0.0	0.5	0.0
Mindi	*Melia azedarach L.*	1	1	2	0.2	0.1	0.3
Pinus	*Pinus merkusii Jungh. & De Vr.*	10	5	1	2.5	0.8	0.2
Pulai	*Alstonia scholaris (L.) R.Br.*	0	0	1	0.0	0.0	0.1

Puspa	*Schima wallichii Noronha*	22	6	35	5.3	1.1	5.3
Rasamala	*Altingia excelsa Noronha*	0	1	0	0.0	0.3	0.0
Renghas	*Gluta renghas L.*	5	0	0	1.3	0.0	0.0
Salam	*Syzygium lineatum (Bl.) Merr. & Perry.*	0	3	0	0.0	0.6	0.0
Seketi	*Eurya acuminate*	0	0	2	0.0	0.0	0.3
Sengon	*Paraserienthes falcataria (L.) Nielsen*	58	92	86	14.0	16.4	12.9
Sungkai	*Peronema canescens Jack*	0	1	0	0.0	0.2	0.0
Suren	*Toona sureni (Bl.) Merr*	0	1	0	0.0	0.3	0.0
Tisuk	*Hibiscus cannabinus L.*	0	3	1	0.0	0.5	0.2
Waru	*Hibiscus tiliaceus L.*	0	0	1	0.0	0.0	0.2
Total		416	566	671			

Shannon-Weiner Index (H') in each dudukuhan type include: i) timber system (0.44), ii) mixed fruit-timber-banana-annual crops system (1.18), iii) mixed fruit-timber system (1.31), and iv) fallow system (1.10). The T-test results for tree diversity (H') in each type of dudukuhan show significant differences between the timber system and both the mixed fruit-timber-banana-annual crop system and the mixed fruit-timber system, at the 1% level. But the differences between the timber system and the fallow system are significant at the 5% level. The tree diversity (H') of mixed fruit-timber-banana-annual crops system indicates no significant difference with the mixed fruit-timber system, but it indicates significant differences at 5% level with the fallow system. Tree diversity (H') of mixed fruit-timber system indicates significant differences at 5% level with fallow system.

Table 2 shows that the priority species are those that occur in almost all dudukuhan types, with high number of trees: *Musa sp.*, *Maesopsis eminii Engl.*, *Paraserienthes falcataria (L.) Nielsen, Artocarpus heterophyllus Lam., Durio zibethinus Murr., Archidendron pauciflorum (Benth.) Nielsen, Mangifera odorata Griff., Euodia latifolia DC., Parkia speciosa Hassk*, *Nephelium lappaceum L.,* and *Schima wallichii Noronha* are the priority species for the Nanggung area.

Table 2. Tree species composition based on dudukuhan types

Local Name	*Botanical Name*	Dudukuhan Types (trees/ha)								Total	(%)
		Timber system	(%)	Mixed fruit-timber-banana-annual crop system	(%)	Mixed fruit-timber system	(%)	Fallow system	(%)		
Fruit Products											
Cempedak	*Artocarpus integer*	0	0.0	1	0.1	2	0.4	0	0.0	2	0.1
Cengkeh	*Eugenia aromatica O.K.*	0	0.0	7	0.9	7	1.6	8	2.2	22	1.0
Duku	*Lansium domesticum*	0	0.0	8	1.0	9	2.0	4	1.1	20	0.9
Durian	*Durio zibethinus Murr.*	1	0.2	11	1.5	14	3.2	5	1.5	32	1.5
Gandaria	*Bouea macrophylla Griff.*	0	0.0	0	0.0	2	0.3	0	0.0	2	0.1
Jambu air	*Syzygium aqueum (Burm.f.) Alston*	0	0.0	0	0.0	1	0.3	0	0.0	1	0.1
Jengkol	*Archidendron pauciflorum (Benth.) Nielsen*	0	0.0	26	3.4	15	3.4	39	10.9	80	3.6
Kapuk randu	*Ceiba pentandra (L.) Gaertn.*	0	0.0	8	1.1	1	0.2	1	0.3	10	0.5
Kecapi	*Sandoricum koetjape (Burm.f.) Merr*	0	0.0	28	3.8	5	1.1	2	0.5	35	1.6
Keluih	*Artocarpus communis J.R. & G.Forster*	0	0.0	1	0.1	0	0.0	0	0.0	1	0.0
Kemang	*Mangifera caesia Jack ex Wall.*	0	0.0	7	1.0	20	4.4	4	1.2	31	1.4
Kemiri	*Aleurites moluccana (L.) Willd.*	0	0.0	1	0.2	3	0.7	0	0.0	4	0.2
Kepayang	*Pangium edule Reinw.*	0	0.0	2	0.3	4	0.9	0	0.0	7	0.3
Kupa gowok	*Eugenia polycephala Miq.*	0	0.0	2	0.3	15	3.3	2	0.4	19	0.9

Kweni	*Mangifera odorata Griff.*	1	0.2	18	2.4	10	2.3	7	2.0	37	1.7
Lamtoro	*Leucaena leucocephala (Lam.) de Wit*	0	0.0	1	0.2	0	0.0	0	0.0	1	0.1
Limus	*Mangifera foetida Lour.*	0	0.0	1	0.1	6	1.3	0	0.0	7	0.3
Mangga	*Mangifera indica L.*	0	0.0	5	0.6	0	0.0	2	0.7	7	0.3
Manggis	*Garcinia mangostana L.*	0	0.0	0	0.0	12	2.6	2	0.6	14	0.6
Melinjo	*Gnetum gnemon L.*	0	0.0	0	0.0	16	3.4	3	0.9	19	0.9
Menteng	*Baccaurea racemosa (Reinw.) Muell. Arg*	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
Nangka	*Artocarpus heterophyllus Lam.*	0	0.0	37	5.0	40	8.7	10	2.9	87	4.0
Pala	*Myristica fragrans Houtt.*	0	0.0	0	0.0	3	0.7	0	0.0	3	0.1
Petai	*Parkia speciosa Hassk.*	0	0.0	25	3.3	11	2.5	12	3.3	48	2.2
Pisang	*Musa spp.*	128	19.9	328	43.8	17	3.7	117	32.7	589	26.8
Rambutan	*Nephelium lappaceum L.*	0	0.0	22	2.9	41	9.1	9	2.5	72	3.3
Timber Products											
Afrika	*Maesopsis eminii Engl*	260	40.6	95	12.7	112	24.6	19	5.4	486	22.1
Calik angin	*Macaranga tanarius*	1	0.1	0	0.0	0	0.0	0	0.0	1	0.0
Cangkalak	*Knema laurina (Blume) Warb.*	0	0.0	0	0.0	4	1.0	0	0.0	4	0.2
Jirak	*Symplocos ferruginea*	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
Kanyere	*Bridelia minutiflora Hook. f.*	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Karet	*Hevea brasiliensis Muell. Arg.*	0	0.0	0	0.0	19	4.3	3	0.9	23	1.0
Kihiang	*Cassia javanica L.*	0	0.0	1	0.1	0	0.0	0	0.0	1	0.0
Kihujan	*Engelhardia spicata Lech. ex Bl.*	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Kihuru	*Litsea noronhae*	3	0.5	0	0.0	1	0.1	2	0.6	6	0.3
Kikacang	*Maniltoa grandiflora Scheff.*	0	0.0	0	0.0	1	0.3	0	0.0	1	0.1
Kirinyuh	*Eupatorium inulifolium H.B.K.*	0	0.0	0	0.0	1	0.1	0	0.0	1	0.0
Kisampang	*Euodia latifolia DC.*	9	1.4	44	5.8	12	2.5	0	0.0	64	2.9
Meranti	*Shorea spp.*	0	0.0	3	0.4	1	0.2	0	0.0	4	0.2
Mindi	*Melia azedarach L*	3	0.4	1	0.1	1	0.3	0	0.0	5	0.2
Pinus	*Pinus merkusii Jungh. & De Vr.*	0	0.0	7	1.0	14	3.0	0	0.0	21	1.0
Pulai	*Alstonia scholaris (L.) R.Br.*	0	0.0	1	0.2	0	0.0	0	0.0	1	0.1
Puspa	*Schima wallichii Noronha*	15	2.4	16	2.1	13	2.9	39	11.0	84	3.8
Rasamala	*Altingia excelsa Noronha*	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
Renghas	*Gluta renghas L.*	0	0.0	0	0.0	0	0.0	7	2.0	7	0.3
Salam	*Syzygium lineatum (Bl.) Merr. & Perry.*	0	0.0	3	0.4	2	0.4	0	0.0	5	0.2
Seketi	*Eurya acuminate*	0	0.0	0	0.0	0	0.0	3	0.9	3	0.1
Sengon	*Paraserienthes falcataria (L.) Nielsen*	219	34.1	36	4.8	6	1.3	56	15.6	316	14.4
Sungkai	*Peronema canescens Jack*	0	0.0	0	0.0	1	0.3	0	0.0	1	0.1
Suren	*Toona sureni (Bl.) Merr*	0	0.0	0	0.0	2	0.4	0	0.0	2	0.1
Tisuk	*Hibiscus cannabinus L.*	0	0.0	2	0.2	4	0.8	0	0.0	5	0.2
Waru	*Hibiscus tiliaceus L.*	0	0.0	1	0.2	0	0.0	0	0.0	1	0.1
Total		641		749		454		357		2200	

Tree density, tree basal area, number of species, and number of total trees are the main characteristics that distinguish the four types of dudukuhan. Table 3 shows the average of tree density, tree basal area, number of tree species, and number of trees based on plot measurement in each type of dudukuhan. Tree density of dudukuhan system ranged from 240 to 511 trees per ha (excluded banana plants). To maximize yield of timber, farmers planted two timber species priority (*Maesopsis eminii Engl.* and *Paraserienthes falcataria (L.) Nielsen*) with a higher density in timber system. Economic pressure on farmers' income makes these species started to harvest in three years. But like the fast growing species, these species can be harvested in five to eight years. Tree basal area varied 6.6 to 15.2 m^2/ha. Mixed fruit-timber system and mixed fruit-timber-banana annual crop system have a higher of tree basal area, number of fruit species, and number of fruit tree than the other systems. This is a result of farmers' strategy to favor fruit trees that maintain fruits for long periods in these systems. Tree density and tree basal area are the lowest in the fallow systems that receive no management and are only visited once in 3-4 months. The large distance of the land to the farmers' house (more than 3 km) explains why this system is never maintained by the farmer. Off-farm employment opportunities is another reason why the farmer can leave this system fallow for 5 to 15 years.

Table 3. The profiles of dudukuhan based on plot measurement (excluded banana plants)

Type of dudukuhan	Tree density (trees/ha)	Basal area (m^2/ha)	Average of species number (per plot)		Average of tree number (per plot)	
			Fruits	Timber	Fruits	Timber
Timber system	511	9.3	0.2	2.6	0.2	33.7
Mixed fruit-timber-banana-annual crop system	423	12.3	7.0	3.6	15.5	15.9
Mixed fruit-timber system	437	15.2	8.1	3.2	19.1	15.0
Fallow system	240	6.6	3.4	2.1	7.3	6.7

Farmers' Perceptions of the Selection and Uses of Tree Species.

Figure 2 explains the perceptions of farmer on tree selection. Tree use value, marketing opportunities, and land tenure status were the main factors (highest rank) for the farmers to select the specific tree species. Fast growth, fruiting period and pest-disease problems were important factors also. Competition for water and nutrients between tree crops could be considered by farmers as well: some fruit and timber species would not be planted closely to one another in order to reduce competition for water and nutrients. Elevation and weather-rainfall are least considered for tree selection by farmers. Government policies still impede farmers' tree selection. The government charges fees to the farmers who sold pine trees (*Pinus merkusii*).

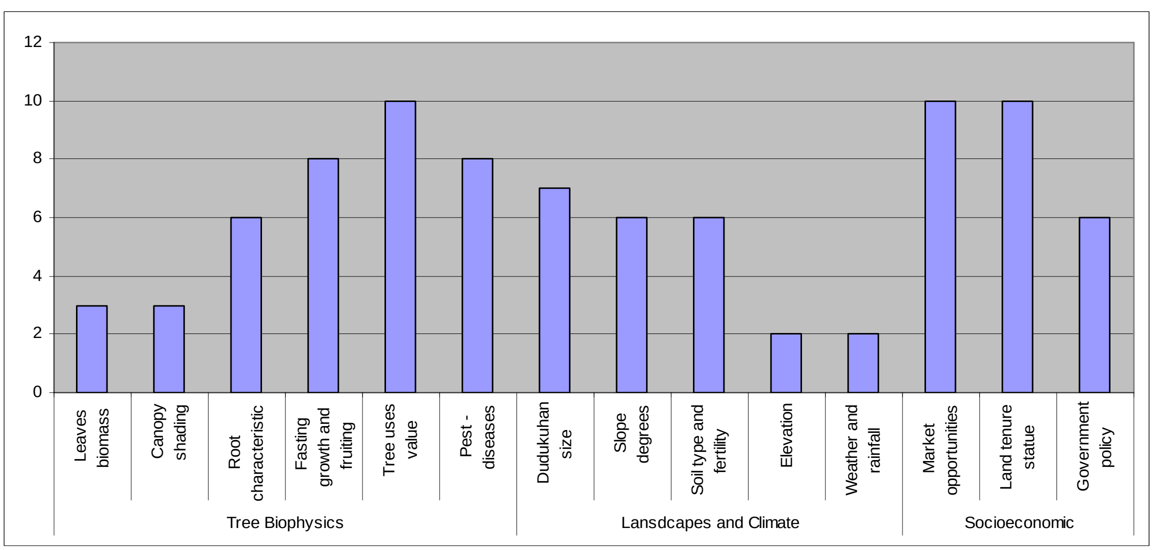

Figure 2. Rank of consideration for tree selection

Figure 3 explains the perceptions of farmer on tree uses. Farmers planted trees in dudukuhan systems to sustain the income of their household (highest rank). A part of the income was used for saving or paying tuitions of their kids. The high rainfall and hilly topography in Nanggung area motivated farmer to plant trees for erosion control. A part of the fruit tree products – that are not sold by farmers – will be uses to meet subsistence needs. A part of the timber products are used for construction and as firewood. Farmers' awareness of the use of the fodder and medicinal tree species is still low.

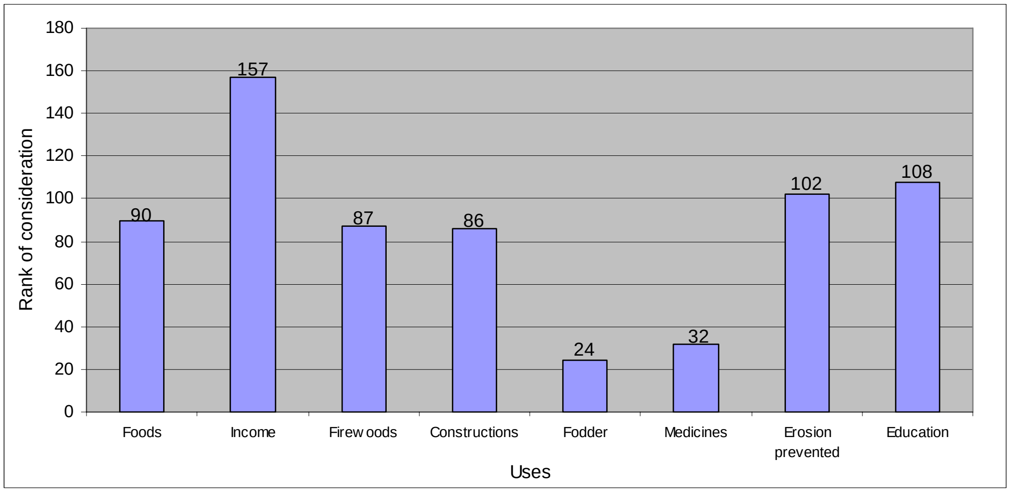

Figure 3. Rank of consideration for tree uses

Management of Dudukuhans. Table 4 shows the results of a study conducted by Budidarsono *et al.* (2004). The study indicates that very little management conducted in dudukuhan systems during the planting season 2002/2003. With regard to labor inputs, based on activities implemented, the data shows that harvesting is the most common activity in the dudukuhan. The study found that chemical fertilizer was applied to around 9 to 10 dudukuhan plots (0.9% of the total plots) and organic fertilizer to around 4 to 5 dudukuhan plots (1.9%). The rate of fertilizer application, for chemical fertilizer was also very low, that is 7.4 kg ha^{-1}, whereas the application of organic fertilizer was reasonably high, up to 4.0 ton ha^{-1}. During the previous year crops were harvested in nearly three-quarters (27.3%) of the dudukuhan plots. Weeding and maintenance of tree or seasonal crops is the next most common activity, conducted 8.9% of the dudukuhan plots. The number of person-days involve in harvesting (7 ps-d/ha) is less than the number of person-days involved in weeding and maintenance (27 ps-d/ha).

Table 4. Level of inputs and returns by type of dudukuhan

Type of dudukuhan	Timber system	Mixed fruit-timber-banana-annual crops system	Mixed fruit-timber system	Fallow system	Total
Number of plots	15	24	38	8	85
Percentage (%)	17.6	28.2	44.7	9.4	100
Total area (ha)	3.82	8.97	15.94	0.43	29.16
Area per plot (ha)	0.254	0.374	0.419	0.054	1.101
Tradable inputs					
Chemical fertilizer					
a. Plots with chemical fertilizer application (%)	-	-	0.9	-	0.9
b. Rate of fertilizer application (kg/ha)	-	-	7.4	-	7.4

Organic fertilizer					
a. Plots with organic fertilizer application (%)	0.5	0.9	0.5	-	1.9
b. Rate of organic application (kg/ha)	1,429	3,000	4,000	-	2,646
Pesticide					
a. Rate of pesticide application (ltr/ha)	-	-	0.001	-	0.001
Labor inputs					
Planting					
a. Plots with planting activity (%)	0.5	0.5	0.9	-	1.9
b. Total labor (ps-d/ha)	8	2	13	-	8
Tree and crop care					
a. Plots with tree and crop care activity (%)	1.4	2.8	4.7	-	8.9
b. Total labor (ps-d/ha)	37	70	14	-	27
Harvesting					
a. Plots with harvesting activity (%)	2.8	9.4	15.1	-	27.3
b. Total labor (ps-d/ha)	7	7	7	-	7
Returns (Rp 000)					
Fruits (Rp/ha)	-	22,111	15,536	-	37,647
Timber (Rp/ha)	5,604	14,345	22,042	-	41,991
Annual crops (Rp/ha)	-	1,485	-	-	1,485
Sum	5,604	37,940	37,578	-	81,122
Net Returns (Rp 000)					
Total	4,900	35,913	34,942	-	75,755
Average per plot	327	1,496	920	-	891
Average per hectare	1,284	4,002	2,192	-	2,598

D. Discussion

The tree diversity in the dudukuhan systems is lower than the tree diversity in the Gunung Halimun National Park (H'=4.05; Suzuki *et al.*, 1997). The natural forest in the national park has achieved a climax for tree diversity, but in the dudukuhan systems periodic enrichment of exotic and indigenous species of fruit and timber trees occurred by farmers. Yet, the periodic enrichment with tree species by farmers does not result in a tree diversity climax such as in the natural forest.

Tree diversity (H'), tree density, and tree basal area of all dudukuhan systems indicate a transformation process of dudukuhan. The transformation process occurred by dynamic changes in tree species composition and number of trees (Table 2-3 and Figure 4). This is farmers' strategy for continuing the productivity of the dudukuhan and enhancing household income (as the main factor), and (as the second factor) preventing erosion. The strategy has a great impact on biodiversity conservation. Indigenous and exotic tree species are usually planted by farmers. The indigenous fruit and timber species are used for meeting the household subsistence needs, but the exotic (introduced) fruit and timber species are sold on the local market to enhance household income. The occurrence of indigenous and exotic tree species in large numbers in dudukuhans demonstrates that they are: (a) adapted to the biophysical conditions of the Nanggung area and (b) meet farmers' subsistence needs.

In general, the transformation of dudukuhan types (Figure 4) can be explained by started from fallow system which is cleared by farmer for establishing *'huma or tegalan'* that intercropping bananas and annual crops for 3 to 4 years. During that period, farmer enriched the huma with a various of fruit and timber species priority such as *Maesopsis eminii* Engl., *Paraserienthes falcataria* (L.) Nielsen, *Artocarpus heterophyllus* Lam., *Durio zibethinus* Murr., *Archidendron pauciflorum* (Benth.) Nielsen, *Mangifera odorata* Griff., *Euodia latifolia* DC., *Parkia speciosa* Hassk, *Nephelium lappaceum* L., and *Schima wallichii* Noronha.

Both the mixed fruit-timber-banana-annual crops system and the timber system are an extended form of the *huma* (*tegalan*). But the timber system could be changed into *huma* again after the farmer has harvested the timber products. Mixed fruit-timber-banana-annual crops system is preferred by the farmer, providing short-term as well as long-term household needs. The farmer harvests bananas and annual crops to meet short-term needs, and *Artocarpus heterophyllus Lam.* and various bamboo species for medium-term needs. The other fruit and timber species provide for long-term needs. Enrichment with fruit and timber species occurred continuously in the mixed fruit-timber system as an extended form of the mixed fruit-timber-banana-annual crops system. In this situation, farmers would not plant the bananas and annual crops in between tree spaces.

At a certain time, the productivity of mixed fruit-timber system decreased and failed to support the income of the household. Then the farmer considered to transform the system into a *huma* (*tegalan*). But if the distance of the mixed fruit-timber system was quite far from the farmer' s house (more than 3 km), the farmer changed the plot into a fallow system. In another case, the farmer's son inherited the fallow system. The son settled at the plot and transformed it into a timber system.

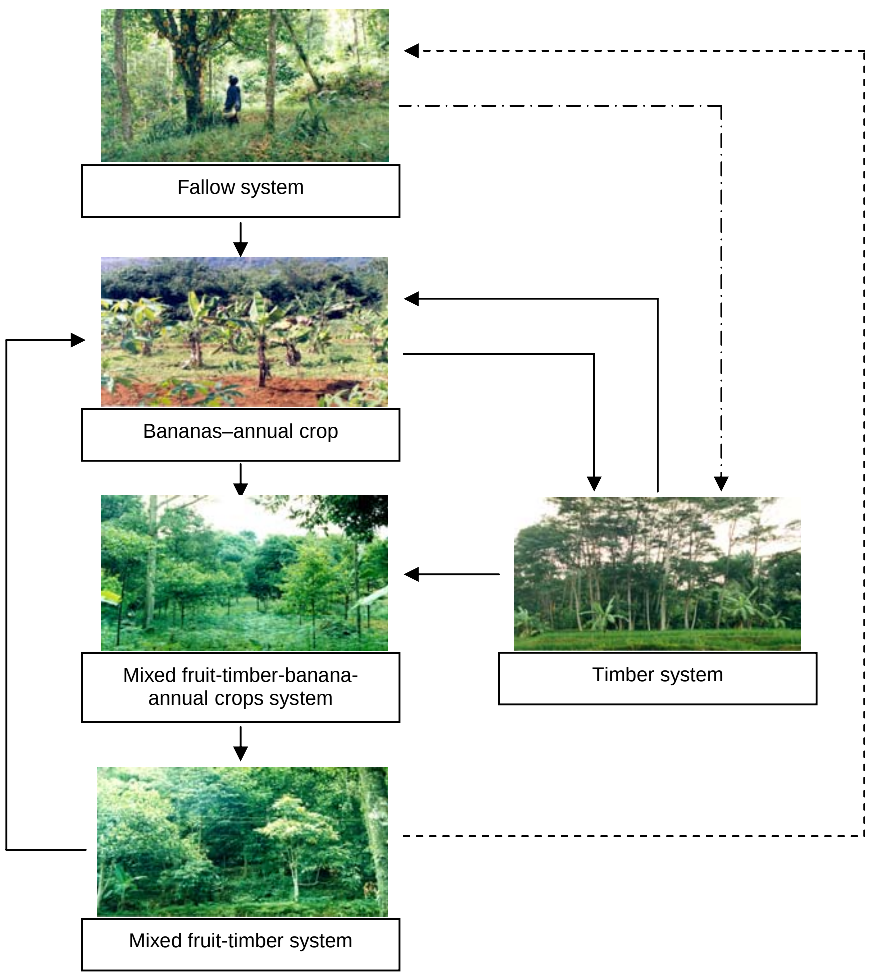

Figure 4. Transformation of dudukuhan types

The regression analysis was conducted to describe the relationship between the profiles of dudukuhan and the number of species and the number of trees. In the regression equation, the number of species and the number of trees function as the *Dependent Variable* (**y**); but the dudukuhan size, tree density, basal area, elevation, and also the number of fruit-timber species, and number of fruit-timber trees function as the *Independent Variables* ($\mathbf{x_1}$, $\mathbf{x_2}$, $\mathbf{x_3}$, ..., $\mathbf{x_i}$). The relationship between the profiles of dudukuhan – such as dudukuhan size, tree diversity, tree basal area, elevation – tended to influence the number of tree species and number of tree on fruit and timber trees.

Table 5. Results of the regression analysis for the dudukuhan timber system

Variable	Timber system			
	Number of species		Number of trees	
	Fruits	Timber	Fruits	Timber
Dudukuhan size (ha)	0.100	0.007*** (+)	0.671	0.586
Tree density (N/ha)	0.328	0.217	0.105	0.016** (+)
Basal area (m^2)	0.621	0.354	0.086* (+)	0.042** (-)
Elevation (m. a. s. l.)	0.521	0.778	0.052* (-)	0.012** (+)
Number of fruit species		0.083* (+)		
Number of fruit trees				0.072* (+)
Number of timber species	0.083* (+)			
Number of timber trees			0.072* (+)	

*** indicates significance at 1% level, ** at 5% level, and * at 10% level.
(+) and (-) indicate relationship between independent variables ($\mathbf{x_i}$) and dependent variable ($\mathbf{y}$)

Statistically, table 5 shows that an increase in the number of timber species and the number timber trees causes an increase in the number of fruit species and number of fruit trees, and vice versa. Although the timber trees are the main trees in this system, farmers initiated to enrich the timber system with some fruit species such as *Durio zibethinus* and *Mangifera odorata*. When both *Maesopsis eminii* and *Paraserienthes falcataria* are harvested after five to eight years, the productivity of the dudukuhan is still supported by fruit trees. In this situation, the timber system transforms into the mixed fruit-timber-banana-annual crops system. During the maintenance period, the farmer keeps a number of fruit trees, but the timber species are harvested earlier for timber products. It causes the fruit tree basal area is higher than the timber tree basal area. This is a result of farmers' strategy to favor fruit trees and maintain fruits for long periods in the system.

The number of fruit trees tends to be higher in the Parakan Muncang village as the downstream area of Nanggung subdistrict than the other sample villages, but the number of timber trees tends to be higher in the Curug Bitung and Cisarua villages – in upstream area (Table 1). Marketing opportunities for fruit products are available in the Parakan Muncang village whereas marketing opportunities for timber products are available in the upstream area. In the upstream area, farmers prefer to enrich the dudukuhan system with timber species when the size of the dudukuhan is expanded. The timber trees are planted at high density, limiting stem growth and the basal area of timber trees.

Table 6. Results of the regression analysis for the dudukuhan mixed fruit-timber-banana-annual crops system

Variable	Mixed fruit-timber-banana-annual crops system			
	Number of species		Number of trees	
	Fruits	Timber	Fruits	Timber
Dudukuhan size (ha)	0.782	0.839	0.140	0.286
Tree density (N/ha)	0.856	0.921	0.569	0.964
Basal area (m^2)	0.957	0.846	0.277	0.195
Elevation (m. a. s. l.)	0.585	0.679	0.431	0.816
Number of fruit species		0.555		
Number of fruit trees				0.297
Number of timber species	0.555			
Number of timber tree			0.297	

*** indicates significance at 1% level, ** at 5% level, and * at 10% level.
(+) and (-) indicate relationship between independent variables ($\mathbf{x_i}$) and dependent variable ($\mathbf{y}$)

Table 6 shows that there is no indicate significance between independent variables (x_i) and dependent variable (y) of dudukuhan in mixed fruit-timber-banana-annual crops system. In general, this system is almost similar with home garden system and some of the plots closed to the farmers' house. Similar with the home garden, farmers maintain the annual crops, fruit and timber trees for household income. Based on Table 4, total labor for tree and crop care activity was highest (70 person-day per ha) than the other dudukuhan systems. Farmers prefer to maintain this system for short-term up to long-term needs. In the planting season 2002/2003, the annual crops, fruit, and timber products contributed IDR 37,940,000 per ha. Net returns that farmer can get from these products is IDR 4,002,000 per ha. Compared to other systems, the mixed fruit-timber-banana-annual crops system gives the highest net returns (average per hectare) to the farmer.

Table 7. Results of the regression analysis for the dudukuhan mixed fruit-timber system

Variable	Mixed fruit-timber system			
	Number of species		Number of trees	
	Fruits	Timber	Fruits	Timber
Dudukuhan size (ha)	0.785	0.498	0.046** (-)	0.619
Tree density (N/ha)	0.371	0.722	0.051* (-)	0.657
Basal area (m^2)	0.740	0.863	0.030** (+)	0.636
Elevation (m. a. s. l.)	0.159	0.022** (+)	0.011** (-)	0.514
Number of fruit species		0.050* (-)		
Number of fruit trees				0.294
Number of timber species	0.049** (-)			
Number of timber trees			0.294	

*** indicates significance at 1% level, ** at 5% level, and * at 10% level.
(+) and (-) indicate relationship between independent variables ($\mathbf{x}_i$) and dependent variable ($\mathbf{y}$)

Transformation from the mixed fruit-timber-banana-annual crops system to the mixed fruit-timber system was conducted by farmer through dynamic changes in tree species and number of trees composition. The dynamic changes in tree species and number of trees composition are based on household needs (Table 2 and Table 7). Some of farmers tend to decrease the number of timber species, by replacing some timber trees with fruit species. And the opposite, some fruit species are replaced with timber species.

In the mixed fruit-timber system, farmers tend to add a number of trees from fruit species although the size of dudukuhan is limited (decreased). They plant the fruit trees at a lower density than the timber trees. Fruit trees planted at a low density result in larger tree basal area. Farmers follow this strategy in order to continue the productivity of dudukuhan by maintaining fruits for long periods. Planting activity in this system is higher than both the mixed fruit-timber-banana-annual crops system and the timber system. Harvesting is the dominant management activity compared to both tree and crop care activity and planting activity in the mixed fruit-timber system. To increase productivity at harvesting time, some of farmers apply both organic and chemical fertilizers. The application of fertilizers in this system is higher than in other dudukuhan systems (Table 4). Mixed timber system is the last dudukuhan system with harvestable fruit and timber products, before farmers transform it to the fallow system.

The availability of market for fruit products in Parakan Muncang village (downstream area) causes farmers to maintain more fruit trees. Budidarsono *et al.* (2004) mention that return gain from fruit products in Parakan Muncang village is higher than in the other sample villages. At the same time, the number of timber species is higher in the upstream area (Curug Bitung and Cisarua villages). Probably, the Gunung Halimun National Park located close to the Cisarua and Curug Bitung villages serves as a source of germplasm for the dudukuhan system in those villages.

Table 8. Results of the regression analysis for the dudukuhan fallow system

Variable	Fallow system			
	Number of species		Number of trees	
	Fruits	Timber	Fruits	Timber
Dudukuhan size (ha)	0.099* (+)	0.164	0.221	0.347
Tree density (N/ha)	0.199	0.619	0.146	0.670
Basal area (m^2)	0.165	0.526	0.242	0.342
Elevation (m. a. s. l.)	0.057* (-)	0.325	0.068* (-)	0.329
Number of fruit species		0.133		
Number of fruit trees				0.393
Number of timber species	0.133			
Number of timber trees			0.393	

*** indicates significance at 1% level, ** at 5% level, and * at 10% level.
(+) and (-) indicate relationship between independent variables ($\mathbf{x}_i$) and dependent variable ($\mathbf{y}$)

The regression results for the fallow system (Table 8) show that the number of fruit species tends to increase with the size of the dudukuhan. But this situation happened in downstream area. In Parakan Muncang village, where the owners of a fallow system never maintain these systems, the local community living in and around these fallow systems tends to allow the growth of fruit trees for the gathering of fruit products.

The farm and household economic study conducted by Budidarsono *et al.* (2004) includes a farm budget analysis for the period of the study for every plot of dudukuhan controlled by the surveyed households. This analysis mainly focused on net returns calculation during 2002/2003 planting year. It should be clarified that net returns in this regards represents net cash inflow for a single year (2002/2003 cropping year), and does not represent land use profitability. Table 4 summarizes the net returns calculation by type of dudukuhan. The results of the analysis show that, except the fallow system, three types of dudukuhan gain positive net returns, meaning that cash inflow was larger than cash outflow. In other words, three types of the dudukuhan provide income to the owners. The dudukuhan systems have a high potential to enhance the productivity and profitability.

Potency of productivity and profitablity of tree farming systems have been shared by many papers. Predo (2002) found that tree farming systems in the Philippines provided annualized income between P8,860 to P60,996/ha/year compared to annual crop production and imperata land use system (P5,352/ha/year and P69/ha/year). Average yearly income of fruit and timber trees in mature damar agroforest (in Krui – Lampung) achieved Rp2,410,000/ha (de Foresta *et al.*, 1995). Fernandez (2004) mentioned that the contribution of benzoin trees (*Styrax benzoin*) to household income can amount to as much as 70% of total income with contribution ranges from US$144 to US$216. In central and east Java, smallholder farmers see tree farming system as a ‘living saving account’ means to diversify their production, reduce risk, build assets to enhance family incomes and security (van Noordwijk *et al.*, 2003).

Most smallholder tree farming systems are characterized by limited proactive management and planning. Dudukuhan and others tree farming system are managed on an traditionally extractive basis, few inputs (quality germplasm, fertilizers, labor, etc) are allocated to these systems. Spacing is irregular and species components often primarily the result of chance. Harvesting products is often the most common management activity, with minimal weeding to control herbaceous and woody competition. As a results, the quality and quantity of products may be far below the systems’ potential.

Farmers are interested in intensifying the management of their dudukuhans, but hesitate because they do not know where and how to focus their efforts. Resource scarcity, absence of knowledge regarding propagation and management, and limited access of market and governments’ policy disincentives/ambiguities are the limited factors for farmers to intensify the management of their tree farming systems (Tolentino *et al.*, 2002; LSU, 2002; and Potter and Lee, 1998). Under conditions of insecure land tenure and market access, smallholder farmers can not and will not cultivate a wide range of tree species as a component of their efficient, integrated and risk-averse livelihood and land-use systems and will not effectively respond to the increased demand for wood products (van Noordwijk *et al.*, 2003). Fernandez (2004) mentioned that government investments to support benzoin production are limited and in most cases have failed because of funds mismanagement.

The productivity of most smallholder tree farming systems can be improved by enhancing smallholder farmer management skills. Empowering motivated smallholder farmers to enhance and diversify productivity and profitablity of their tree farming systems conducted by a series initial trainings that a) analyze existing conditions and problems, b) identify technical options that focus on farmers' priorities (tree propagation and nursery management, tree and farming system management, post harvest handling, and farmer-operated semi-commercial enterprises), and c) develop farmer group workplans.

To mobilize self-interest of farmers in Nanggung may be best served by transforming their traditional subsistence tree farming systems into semi-commercial enterprises that yield products to meet both home and market demand. This process requires that farmers: 1) focus on a limited number of tree species that are appropriate for local biophysical conditions and a high market value/demand; 2) utilize high quality germplasm (provenances, clones, and seed source) to increase productivity and profitability; 3) manage the dudukuhans to yield tree products that meet market specifications and conservation controls; and 4) develop permanent market linkages. Improving quality of germplasm may be achieved through tree propagation training and nursery management techniques.

Through deliberate management, polyculture tree gardens can be developed based on four or five priority tree species – which yield products with high market values, but also contain a number of other valuable species such as indigenous species to serve household needs and reduce risks. When possible, harvesting at different ages through intercropping with short-rotation crops is encouraged to provide products and income during the establishment phase of priority tree species. The additional dudukuhan products resulting from deliberate management can be used in the home (to improve family diet, food security and health) or sold at markets. The greatest benefit to family livelihood is to sell these products at high-demand markets in Bogor and Jakarta, and potentially through international linkages.

Farmer-designed trials (FDT) and participatory evaluation are low-cost methods to increase farmer participation in species evaluation and agroforestry technology development process for their specific biophysical and socioeconomic conditions, as well as to enhance the effectiveness of research activities to meet farmers' needs and improve their welfare (Franzel *et al.*, 1998).

A rapid marketing study need to conduct to assist motivated smallholder farmers on identifying and understanding marketing aspects as following: a) tree farming species and products that hold potential for farmers (product specifications, quantities, seasonality, etc.), b) market channels that are used and hold commercial potential for smallholder products, c) marketing problems faced by farmers and market agents, d) opportunities to improve the quality and quantity of farmers' tree farming products, e) market integration (through vertical price correlation and price transmission elasticity) and efficiency (Roshetko *et al.*, 2006).

To raise incomes significantly, motivated smallholder farmers through 'marketing group' need to analyse the value chain in the market and establish a competitive position. This may mean improving production and marketing technology, product quality and reliability of supply (Scherr *et al.*, 2002). To strengthen the marketing farmer group organizations and improving marketing for dudukuhan products may be achieved through a series of activities in marketing workshops including: a) discussions on the rapid marketing study findings between farmer groups and traders (local, regional or exporter) in the training-workshop, b) visits of farmer groups to various markets (local, regional, and supermarket), c) village meetings between farmer groups and traders, d) visits of regional traders to farmers' plots, e) farmer groups' practice of harvesting and post-harvesting techniques (Roshetko *et al.*, 2004).

Agriculture and forestry extension officers in district level, sub-district government, NGOs, agriculture and forestry private sectors (traders), and agriculture-forestry research institutes may participate in the innovation of the dudukuhan system through the extension approach, strengthening farmers' technical and group management skills and empowering farmer groups to compete for marketing opportunities. The multi-stakeholders shared roles with providing accessibility for inputs, information, and a series of workshops.

Scherr *et al.* (2002) mentioned that strategic business partnerships can benefit both traders (included private industry) and farmer 'marketing' group. Through these arrangements, traders can access timber and non-timber products at a competitive cost, along with tree farming systems asset protection, local ecosystem expertise and social branding opportunities. Business partners can provide farmer 'marketing' group with high-quality planting materials, technical assistance, quality control, investment resources for expansion and marketing and business expertise. An effective partnership requires a long-term perspective for business development, flexible contract terms, special attention to reducing business risk, and mechanisms to reduce transaction costs. Industrial partners need to respect the diversified livelihood strategies of farmer 'marketing' group as the partner.

E. Conclusion

Dudukuhan is a traditional tree farming system with a high diversity of tree. Dynamic changes in tree species composition and number of trees in each of dudukuhan system is farmers' strategy to continue the dudukuhan productivity, adjust to changing market opportunities, enhance their income and prevent erosion. Traditional-extractive management, low inputs, and low productivity are the main problems in the dudukuhan systems.

Empowering motivated smallholder farmers to enhance and diversify productivity and profitablity of their tree farming systems conducted by transforming their traditional subsistence tree farming systems into semi-commercial enterprises that yield products to meet both home and market demand. This process requires that farmers: 1) focus on a limited number of tree species that are appropriate for local biophysical conditions and a high market value/demand; 2) utilize high quality germplasm (provenances, clones, and seed source) to increase productivity and profitability; 3) manage the dudukuhans to yield tree products that meet market specifications and conservation controls; and 4) develop permanent market linkages.

Integrating collaboration between multi-stakeholders through extension approaches may improve management skills of smallholder farmers on tree propagation and nursery management, tree and farming system management, post harvest handling, and farmer-operated semi-commercial enterprises.

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