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The forest garden system of Saparua island, Central Maluku, Indonesia, and its role in maintaining tree species diversity

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Abstract

The *dusuns* of Central Maluku which improve fallows by planting spice trees such as clove (*Syzygium aromaticum* syn. *Eugenia aromatica*), nutmeg (*Myristica fragrans*), or coconut (*Cocos nucifera*) and tending spontaneous regeneration, are an example of a species-rich forest garden system in the eastern hemisphere of the Indonesian archipelago. In this paper we report the influence of site conditions, as slope inclination, soil type, and soil depth, on species composition, tree species diversity, and stand structure in old *dusuns* in four villages on Saparua, a small island south of Seram. In addition, we compared the floristic composition and stand structure of old *dusuns* with those of primary forest and advanced fallow vegetation (~15-yr old). Soil conditions, particularly the depth of the mineral soil layer, and the relief have a major influence on species selection in *dusuns*. The most common species in old *dusuns* were absent both in primary forest and forest fallow. Floristic similarity between old *dusuns* and the unmanaged stands was low. However, in two study villages species richness of old *dusuns* was similar to that of the primary forest. Old *dusuns* showed an open structure with an average reduction of basal area by about half compared to the primary forest. Less than half of all individuals found above 10 cm DBH in old *dusuns* were planted. Only very few species were exclusively planted. Most species were both planted and emerged from spontaneous regeneration. The results indicate the important role of spontaneous regeneration in this forest garden system.

Introduction

Farmers in Southeast Asia have developed a great variety of land use systems to be classified as either homegardens or forest gardens, which are an important source of supplementary subsistence and/or income. In contrast to forest gardens, homegardens are confined to the area immediately surrounding the home (Wiersum, 1982; Michon, 1983; Soemarwoto and Conway, 1991). In the western hemisphere of Indonesia's outer islands (outside Java and Bali) there are many examples of species-rich forest garden systems, ranging from *lembo ladangs* (Sardjono, 1990) and *tembawangs* (Sundawati, 1993; de Jong, 1995), where domesticated fruit trees and original forest trees dominate, over rattan (mainly *Calamus* spp.) (Godoy and Feaw, 1991; Arifin, 1995) to latex-producing rubber (*Hevea brasiliensis*) (Gouyon et al., 1993) and resin-producing damar (*Shorea* *javanica*) gardens (Torquebiau, 1984). In the eastern part of Indonesia, the *dusun* system of Central Maluku is another example of a forest garden system. Although the spice trees clove (*Syzygium aromaticum* syn. *Eugenia aromatica*) and nutmeg (*Myristica fragrans*) are the major components, the term *dusun* is extended to all agroforestry systems containing perennial crops. As this forest garden system is poorly documented to date, we will briefly summarize its main features.

The establishment of a *dusun* starts with the cutting of a patch of pristine forest, while fruit trees are spared. In some villages the slashed patch is not burnt prior to cropping. The site prepared for cropping is called 'garden'. Principal crops are cassava (*Manihot esculenta*), maize (*Zea mays*) and taro (*Colocasia esculenta*). The cropping phase lasts 3–4 years. Thereafter the site is left fallow for 10–20 years. However, the forest fallow phase can be shortened to 5–10 years, if a 'new *dusun*' using perennial crops such as clove, coconut and fruit trees is established. In new *dusuns* the open canopy still allows intercropping. The new *dusun* changes to 'young *dusun*' when intercropping is abandoned owing to canopy closure. Spontaneous regeneration of 'useful' tree species is tended in both phases, resulting in an increasing tree species diversity with time. New and young *dusun* have been established by the current generation of farmers, while 'old *dusuns* have been already managed by the father and grandfather of the present owner (Pattinaya, pers. comm., 1998). In some cases, the 'garden-fallow-*dusun*' pathway is reduced to an immediate establishment of the *dusun* after forest clearing. If primary forest is becoming scarce, old *dusuns* are cleared to establish new cropland. Most *dusuns* are privately-owned. However, the management of *dusuns* is regulated by a series of customary practices, administrative procedures, laws and rituals called *sasi* that limit access and use of resources in certain places at certain times. *Sasi* is imposed by the village head and policed by an elected supervisor of village *dusuns* (Monk et al., 1997).

Similar to the *dusuns* of Central Maluku, most of the above mentioned forest garden systems have been developed in former swidden areas. The other feature in common is that through planting and tending spontaneous regeneration farmers may accumulate a high tree species diversity in forest garden systems. In this study we investigate to what extent different site conditions and management practices influence the tree diversity and stand structure of old *dusuns* on a small island in Central Maluku. Also, we ask how close species composition and stand structure of old *dusuns* resemble primary forest and advanced forest fallow vegetation. Finally, we compare our results with other studies focusing on species diversity in forest garden systems.

Material and methods

The study was conducted on Saparua island (3°30′–40′ S, 128°32′–40′ E) which is located south of Seram in Central Maluku (Figure 1). Average annual rainfall is 340 mm with a peak rainy season from May to August, in the remaining part of the year monthly precipitation is around 100 mm. Mean annual temperature is about 26 °C (Loran, 1991). Saparua has an undulating landscape with mountain ranges in the western and eastern part rising up to 521 m asl. The parent material is volcanic andesite.

Saparua covers an area of 19,800 ha. Most area is marginal land (16,164 ha) as either degraded secondary forest or areas invaded by *Imperata cylindrica, Chromolaena odorata* and *Melastoma* spp. (the former succumbs to the latter species; L. Kammesheidt, pers.obs.). *Dusuns* cover 2,738 ha and the remaining part is occupied by settlements (898 ha) (Anonymous, 1997). Primary forest on Saparua is only found in traditionally protected areas which belong to each village. In recent years, however, because of the limited area of arable land, most villages have converted these protected areas into *dusuns*. Little was known about the structure and species composition of natural vegetation types on Saparua prior to this study. However, the short distance to Seram suggests that common tree species found in the southwestern part of that island like *Shorea selanica, Pometia pinnata, Syzygium* spp. and *Canarium* spp. (cf. Monk et al., 1997) were also once widely distributed on Saparua.

The population on Saparua is concentrated in low lying areas along the coast, except for the eastern part which consists of steep slopes.

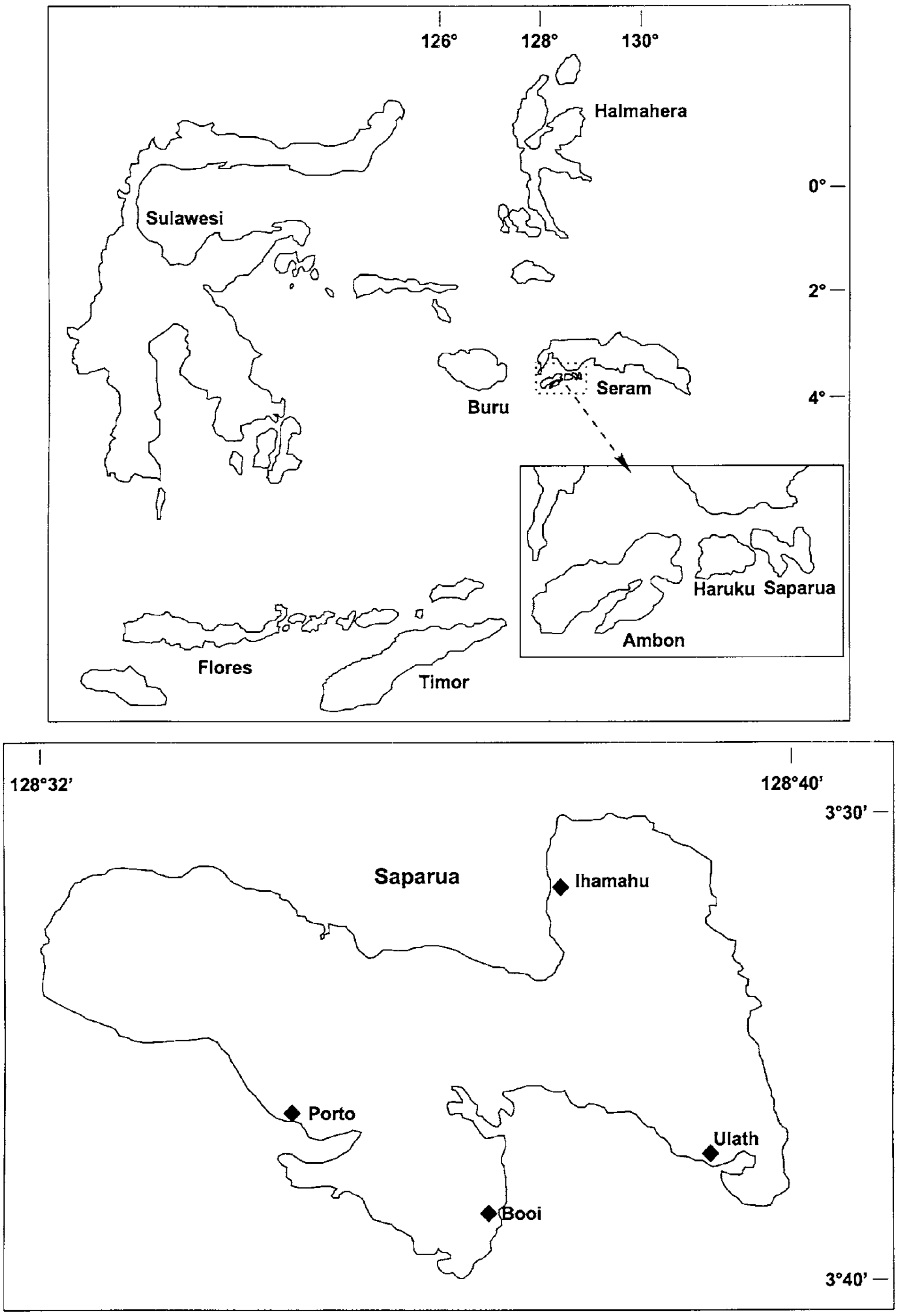

Figure 1. Location of the study area, Central Maluku, Indonesia.

Population size has increased from 34.261 in 1987 to 37.357 in 1997, corresponding to a population density of 173 and 189 person/km^2, respectively (Anonymous, 1997). Most people are Christians (86%) who traditionally practice the *dusun* agroforestry system. Muslim people (14%) adapted this land use system to some extent.

Selection of study sites

The four study sites in Ihamahu, Ulath, Booi and Porto represent a cross-section of the different site conditions, i.e., topography, soil type, and soil depth, found on Saparua (Figure 1). In each village, *dusuns* stretch from the coast into the hinterland. All study sites are Christian villages which follow the traditional *dusun* management system. Apart from old *dusuns*, primary forest and an advanced forest fallow (~15-yr old) were sampled in Ihamahu. In the other study sites, unmanaged forests were restricted to young forest fallows (< 5-yr old).

Sampling system and data collection

In each study village, transect lines in systematic distances were laid out to determine the topographic position of old *dusuns* using three categories of slope inclination (< 5%, 5–20%, > 20%). A soil drilling was made in each old *dusun* encountered along the transect line in order to determine the soil type and soil depth.

Dusuns in Ihamahu and Ulath are mainly located in flat terrain and on gentle slopes (< 5% and 5–20% inclination). Soil types were Inceptisols and Spodosols in the flatter parts, and Entisols in the hilly areas. The mineral horizon was in all cases > 30 cm deep. In Booi and Porto, most old *dusuns* were situated on gentle and steep slopes (> 20% inclination). In Booi, Inceptisols and Entisols with a soil depth > 30 cm dominated. By contrast, in Porto chiefly very shallow Entisols (soil depth < 30 cm on ~75% of the area surveyed) were found; the remaining part stocked on Spodosols and Inceptisols.

Based on this preliminary survey, a stratified random sampling system was applied. In old *dusuns* of Ihamahu and Ulath 10, 10 and 5 plots of 10 m × 20 m (200 m^2) each were established in flat terrain, and on gentle and steep slopes. In Booi 5, 5 and 10 plots, respectively were put in the different topographic categories. In Porto, 10 plots were laid out in the gentle slope category, and 5 plots each in the other two categories. In the primary forest and forest fallow, 39 and 20 plots, respectively were established. Thus, the total sampling area in old *dusuns*, primary forest and forest fallow was 1.8, 0.78 and 0.4 ha. Within each plot trees and palms > 10 cm DBH (diameter at breast height, or 10 cm above buttresses) were measured and identified. In old *dusuns*, saplings (1.30 cm tall – 9.9 cm DBH) were recorded in a strip of 4 m × 20 m (80 m^2) nested in the major sampling unit. Based on farmer's information, trees and saplings were categorized into 'planted individuals' and 'spontaneous regeneration'.

Data analysis

To quantify and contrast species dominance within and among stand types (*dusuns*, primary forest, and forest fallow) we calculated the Importance Value (IV) for each species, as the sum of relative density, relative frequency and relative dominance (basal area). The G-test (Sokal and Rohlf, 1981) was used to test for independence in the distribution of species which were either 'exclusively planted' or emerged 'exclusively by spontaneous growth', and species with both modes of regeneration in old *dusuns*. Species diversity of stand types was calculated by using the Shannon-Wiener H' index and Evenness value (Magurran, 1988). Floristic similarity between stand types was calculated with the qualitative index of Soerensen, considering the species common to both sites and with the quantitative index, which accounts for the relative abundance of shared species (Magurran, 1988).

Results

Species composition

Clove tree (*Syzygium aromaticum*), coconut palm (*Cocos nucifera*) and nutmeg tree (*Myristica fragrans*) were the dominant components in old *dusuns* (Table 1). However, the proportion of these species differed widely among the study sites. In

Table 1. The most common tree and palm species in old *dusuns* ranked by their Importance Value (IV), and values found in primary forest and forest fallow on Saparua island, Central Maluku, Indonesia.

Species (family)	Main use(s)	IV (%) in old *dusuns*					IV (%) in	
		Ihamahu (0.5 ha)	Ulath (0.5 ha)	Booi (0.4 ha)	Porto (0.4 ha)	Total	Primary forest (0.78 ha)	Forest fallow (0.4 ha)
Syzygium aromaticum (L.) Merr. (Myrtaceae)	Sp	84.8	134.6	61.3	52.5	333.2	–	–
Cocos nucifera Linn (Palmae)	Fo, Ct	33.5	13.5	1.9	106.2	155.1	–	–
Myristica fragrans Houtt (Myristicaceae)	Sp	17.1	14.2	83.8	5.5	120.6	–	–
Canarium commune P. Blanco (Burseraceae)	Fo, Ct, Fu	38.1	8.4	25.6	2.3	74.4	6.8	–
Arenga pinnata Merrill (Palmae)	Al, Hi	–	28.8	–	5.1	33.9	3.2	–
Metroxylon rumphii Mart. (Palmae)	Fo, Rt, Pa	13.8	–	–	16.0	29.8	–	–
Durio zibethinus Moon (Bombacaceae)	Fo, Ct	11.4	2.0	9.6	–	23.0	0.6	–
Bouea macrophylla Griff. (Anacardiaceae)	Fo	19.1	2.5	–	–	21.6	–	–
Parkia speciosa Hassk. (Leguminosae)	Fo	–	2.5	12.7	5.9	21.1	–	–
Gmelina moluccana Backer (Verbenaceae)	Ct, BM	8.0	–	2.4	4.8	15.2	–	–
Mangifera indica Blume (Anacardiaceae)	Fo	–	1.8	1.8	10.7	14.4	–	–
Lansium domesticum M.N. Correa (Meliaceae)	Fo	–	1.8	6.3	5.6	13.7	0.6	–
Areca catechu Linn (Palmae)	To, Pa, Fu	–	3.6	5.9	–	9.5	1.2	–
Inocarpus edulis T.F. Forst (Leguminosae)	Fo, Ct	4.8	–	–	4.4	9.2	–	–
Canarium silvestris Gaertn. (Burseraceae)	Ct, Fo	2.0	–	7.0	–	9.0	36.0	2.3
Cerbera manghas Linn (Apocynaceae)	Fe	–	3.6	5.4	–	9.0	–	9.0
Toono sureni Merrill (Meliaceae)	Bm, Fu	1.5	2.5	–	4.7	8.7	0.6	–
Aleurites moluccana H.B. Willd (Euphorbiaceae)	Ct, Sp, Pc	–	4.0	–	4.0	8.0	–	2.4
Cananga odorata Hook. (Annonaceae)	Sp	1.4	1.9	4.3	–	7.6	4.1	–
Metroxylon sago Kon. (Palmae)	Fo, Rt, Pa	1.4	–	–	6.0	7.4	–	–
Subtotal		237.2(13)	225.9(15)	228.0(13)	233.7(14)		53.1(8)	13.7(3)
Other species		62.8(36)	74.1(32)	72.0(31)	66.3(22)		246.9(50)	286.3(27)
Total		300.0(49)	300.0(47)	300.0(44)	300.0(36)		300.0(58)	300.0(30)

Main use(s) of species are indicated as: Al = Alcohol; Bm = boat making; Ct = construction timber; Fe = fencing; Fo = food item, as either from fruits or, in case of palms, from the starch of stems; Fu = furniture; Hi = household items; Pa = panelling; Pc = protective coating of boats; Rt = roof thatching; Sp = spice; To = tobacco. Area sampled and number of species appear in parenthesis.

Ihamahu and Ulath, clove was the main species, while in Booi and Porto nutmeg and coconut, respectively were the most common species. In Booi, small nutmeg trees are growing on steep slopes under the shade of tall fruit trees like *Canarium commune*. Clove, by contrast, dominated on gentle slopes. In the largely shallow soils of Porto the coconut palm is the first choice, while in sites with deeper mineral soil clove was found to be most common. Of local importance are for example *Arenga pinnata*, using the palm sap to make alcohol, *Metroxylon rumphii* which is used for a variety of products, and *Parkia speciosa* and *Mangifera indica* cultivated for their fruits. All listed tree species are also used for fuelwood. Some species have medicinal value. The bark, seed and fruit of *Lansium domesticum* and *C. nucifera* for instance are used to treat fever and malaria. The clove flower and *Areca catechu* seeds are a remedy against toothache.

The most common useful species in old *dusuns* were not found in either the primary forest or forest fallow. However, the genera *Syzygium* and *Myristica* were represented by non-commercial species in the primary forest. Dominant tree species in primary forest were *Gluta renghas* Linn. (Anacardiaceae), *Pometia pinnata* T.F. Forst (Sapindaceae) and *Myristica globosa* Warb. (Myristicaceae) with an Importance Value of 46.8, 42.7 and 40.4%, respectively; palm species such as *Arenga pinnata* played only a minor role in species composition. In the forest fallow, the secondary species *Mallotus paniculatus* Muell. Arg. (Euphorbiaceae) and *Timonius timon* Merrill (Rubiaceae) were the predominant components showing an Importance Value of 156.8 and 34.9%, respectively; palm species were absent in the forest fallow. Only few of the common species in old *dusuns* were found in the forest fallow, while about half of the important species in old *dusuns* were also encountered in the primary forest.

In old *dusuns*, the highest tree and palm species richness was found in Ihamahu. Species richness between Ihamahu and Ulath was only slightly different, while pronounced differences were found between Ihamahu and Porto. The highest number of species was recorded in the primary forest. However, with a larger sample size species richness in Ihamahu and Ulath might reach values similar to the primary forest. The forest fallow showed the lowest number of species. Overall, 147 tree and palm species (≥ 10 cm DBH) belonging to 46 families were recorded.

Species diversity and stand structure

Species and stem density were similar between slope categories in the old *dusuns* of the different villages so that data were pooled (Table 2). Likewise, species and stem density varied only slightly among villages and between villages and the forest fallow. In contrast, the primary forest showed a clearly higher species and stem density than both old *dusuns* and the forest fallow. The

Table 2. Species number per plot, Shannon-Wiener index H′, evenness (E), stem number per plot, basal area ($m^2\ ha^{-1}$) and stem density per hectare of trees and palms > 10 cm DBH in old dusuns, forest fallow, and primary forest on Saparua island, Central Maluku, Indonesia.

		No. spp./200 m^2				No. stems/200 m^2				Percentage distribution in	
	n	range	mean ± SD	H′[1]	E[2]	range	mean ± SD	$m^2\ ha^{-1}$	N ha^{-1}	planted	spontaneous
Old *dusuns*											
– Ihamahu	25	1–7	4.0 ± 1.7	3.12	0.91	2–10	6.1 ± 1.8	17.8	151	45	55
– Ulath	25	2–6	3.4 ± 1.3	2.87	0.72	4–9	6.4 ± 1.4	24.6	160	31	69
– Booi	20	2–7	4.6 ± 1.4	2.73	0.77	2–10	7.4 ± 2.0	15.2	146	27	73
– Porto	20	1–7	3.2 ± 1.4	2.81	0.71	4–10	6.9 ± 1.5	15.4	139	29	71
Forest fallow	20	1–6	3.6 ± 0.9	2.35	0.70	1–13	6.3 ± 2.5	1.9	125	–	100
Primary forest	39	3–13	8.0 ± 2.1	3.22	0.89	6–20	10.7 ± 3.2	37.5	412	–	100

[1]$H' = -\Sigma\ p_i \ln p_i$ where p_i is the proportion of individuals of species i in the community (Magurran, 1988); [2]$E = H'/H_{max}$; H_{max} indicates a situation where all species are found equally abundant. The percentage of planted and spontaneous regeneration was calculated on the basis of the overall stem density in the different sites.

H′ and Evenness values were highest in Ihamahu and the primary forest.

In old *dusuns*, the basal area was reduced by more than a half compared to the primary forest, except for Ulath. The even more reduced stem density per hectare in old *dusuns* compared to the primary forest indicates that in the former managed sites relatively few and tall trees are widely spaced in order to increase production. The relatively high basal area in Ulath is due to the mix of species mainly used, i.e., *S. aromaticum, A. pinnata, M. fragrans*, and *C. nucifera* (cf. Table 1) which allows for narrow spacing. In Booi, the low basal area may be ascribed to the fact that many tall shade trees such as *Canarium* spp. and *D. zibethinus* died off in the last few years. The largely marginal soils in Porto limit the use of perennial crops. Major crop species are *S. aromaticum* and *C. nucifera* which require full overhead light for optimal production so that a wide spacing is applied. Similar major crop species are found in Ihamahu. However, the commonness of fruit trees such as *C. commune* (cf. Table 1) indicates the more favorable site conditions which contribute to a higher basal area compared to Porto. The low basal area and stem density in the forest fallow is partly due to the fact that this site is used as source for fence posts. Regular cuttings hinder trees from growing tall (L. Kammesheidt, pers. obs.). About half of all trees found in Ihamahu were planted, while in the other sites spontaneous regeneration dominated over planted individuals.

Species and stem density at sapling stage

Data for species and stem density for the individual village were pooled, because only slight differences were found between slope categories (Table 3). Species and stem density were similar among villages, except for Porto. Species diversity measured by the H′ and Evenness value was highest in Ihamahu and lowest in Porto. The light canopy of dominating coconut palms in old *dusuns* of Porto supports the invasion of *I. cylindrica* and *Melastoma* spp. which smother the growth of useful trees. Frequent weeding carried out to liberate tree regeneration from grass and shrub competition seems to be rather indiscriminate (M. Kaya, pers. obs.), resulting in the reduction of the already low numbers of trees. The close canopy structure in old *dusuns* of the other villages is an efficient protection against the invasion of the aforementioned species. The relatively high species and stem density in Booi was due to the abundant regeneration of the most common tree species, *M. fragrans, C. commune, D. zibethinus*, and *P. speciosa*. The proportion of planted individuals recorded at sapling stage was lower than at tree stage (cf. Table 2), suggesting that planted trees are more carefully tended than spontaneous regeneration.

Methods of regeneration on species level

Exclusively planted tree species played only a minor part in the overall species diversity (Table 4). However, the pattern of the mode of establishment was different between study sites. While in Ihamahu one species was found to be exclusively planted, 11 species felt into this category in Ulath. Modes of establishment in the other sites were similar to the average values. Individuals of the four most common species (cf. Table 1) were generally both planted and emerged from spontaneous regeneration, except for *M. fragrans* which was exclusively planted in Ulath and Porto.

Floristic similarity

The highest floristic similarity based on the qualitative Soerensen index was found between Ihamahu and Ulath as well as between Ihamahu and Porto (Table 5). In general, more species in common were found in old dusuns and the primary forest than in old *dusuns* and the forest fallow, except for Porto. Floristic similarity was highest between old *dusuns* in Ihamahu and the primary forest which may be due to the close distance between these stands. The quantitative Soerensen index showed similar values among study sites, suggesting that species in common are represented with a roughly equal proportion of individuals in the species composition between stands. In all cases, floristic similarity between old *dusuns* was less than 50%, indicating the fairly distinct set of species in the different study sites.

Table 3. Species number per plot, Shannon-Wiener index H′, evenness (E), stem number per plot and stem density per hectare of saplings (130 cm tall–9.9 cm DBH) in old *dusuns* on Saparua island, Central Maluku, Indonesia.

		No. spp./80 m^2				No. stems/80 m^2			Percentage distribution in	
	n	range	mean ± SD	H′	E	range	mean ± SD	N ha^{-1}	planted	spontaneous
Ihamahu	25	1–4	1.7 ± 0.9	2.80	0.90	1–5	2.8 ± 1.5	210	2	98
Ulath	25	1–3	1.6 ± 0.9	2.57	0.81	1–5	2.4 ± 1.4	195	23	77
Booi	20	1–3	2.1 ± 0.8	2.68	0.88	1–5	3.0 ± 1.2	205	12	88
Porto	20	0–2	1.0 ± 0.6	2.30	0.73	1–3	1.6 ± 0.9	100	19	81

The percentage of planted and spontaneous regeneration was calculated on the basis of the overall stem density in the different sites.

Table 4. Number of 'exclusively planted' species, and species which either emerged 'exclusively from spontaneous regeneration' or with both modes of regeneration in old *dusuns* (trees and palms ≥ 10 cm DBH) on Saparua island, Central Maluku, Indonesia.

	Mode of establishment				
	Planted	Spontaneous	Both	Total	*P*
Ihamahu	1	18	30	49	*
Ulath	11	14	22	47	*
Booi	5	14	23	42	n.s.
Porto	7	11	18	36	n.s.
Average	6.0	14.3	23.3	43.6	

The different modes of establishment in the individual study site were tested against the average pattern. * = $P < 0.05$. Not significant if $P > 0.05$ (n.s.).

Table 5. β-diversity between stands (trees and palms ≥ 10 cm DBH) based on the qualitative Soerensen index (C_S) and the quantitative index, considering the lower sum of individuals found in both sites (C_N) on Saparua island, Central Maluku, Indonesia.

C_N / C_S	Ihamahu	Ulath	Booi	Porto	Forest fallow	Primary forest
Ihamahu	–	0.43	0.26	0.40	0.20	0.38
Ulath	0.42	–	0.35	0.36	0.15	0.26
Booi	0.26	0.40	–	0.37	0.29	0.26
Porto	0.42	0.41	0.33	–	0.28	0.12
Forest fallow	0.18	0.10	0.22	0.24	–	0.12
Primary forest	0.39	0.29	0.26	0.15	0.21	–

$C_S = 2j/(a + b)$; Magurran (1988), where j = the number of species common to both sites; a = the number of species in site A, and b = the number of species in site B.

Discussion and conclusions

Old *dusuns* are complex, species-rich forest gardens which constitute the end product of an intensive, knowledgeable land use system. Similar to other forest garden systems in Indonesia, *dusuns* are established in swidden areas (cf. Sardjono, 1990; Sundawati, 1993). However, while in some forest garden systems planted species merely complement the set of spontaneous regeneration, the starting point of *dusuns* is the establishment of a clove or coconut plantation in open areas. Nutmeg, by contrast, as shade-requiring species is planted under the canopy of tall trees such as *Durio* *zibethinus* and *Canarium commune*. The tending of spontaneous regeneration results in an increase of species richness in the course from new to old *dusuns*, though the dominant position of the plantation crop is maintained by replacing senescent individuals on small scale.

The selection of principal crop species and subsequent overall species diversity is apparently influenced by individual site conditions. The mostly marginal site conditions in Porto result in a lower tree species diversity compared to the other villages. De Jong (1995) who studied *tembawangs* in West Kalimantan found that the timing of the establishment of a garden and the management intensity has a major impact on the stand structure and species composition. The *tembawang* that was only established after the area had already been degraded to *Imperata* grassland and experienced thereafter trials with various crop trees showed a considerably lower species diversity and number of stems than *tembawangs* immediately established after the rice was harvested. Similar to the present study, most *tembawangs* had a lower number of trees, basal area and species diversity compared to primary forest. Overall, however, tree species diversity in old *dusuns* was more similar to primary forest than either de Jong's (1995) *tembawangs* or the rubber gardens of Michon and de Foresta (1995).

Forest gardens on larger islands like Kalimantan also harbour species without any known economic value which are generally not removed (Sardjono, 1990; Sundawati, 1993). In other parts of Kalimantan indigenous swidden farmers intensively use secondary vegetation without transforming it into forest gardens (Colfer, 1997). In old *dusuns* on Saparua, by contrast, any species found yields a useful product. Thus the tight interdependence of humans and the surrounding (cf. Ewel and Högberg, 1995) is probably earlier reached on small than on large islands. The high species diversity in old *dusuns* ensures a steady supply of nearly all kinds of goods for daily needs. Salafsky (1994) who studied mixed-fruit gardens in the Gunung Palung region of West Kalimantan found that improved market access in recent years owing to road construction has led to cultivating only few commercial species which fetch a high market price. Opportunities for an increased commercialization of *dusuns* are limited because of the remoteness of Saparua. People have found a compromise between subsistence farming and cash income mainly generated from clove and nutmeg cultivation. In contrast to Sumatra and Kalimantan where logging and transmigration schemes have led to an abandonment of traditional land use systems (Sardjono, 1990; Michon and de Foresta, 1995; Colfer, 1997), the *dusun* system on Saparua may be not under immediate threat owing to its relatively isolated location. However, people are now tending to plant more cash crops, especially clove (cf. Monk et al., 1997). Also, 'new' cash crops such as cacao (*Theobroma cacao*) have been recently introduced by the extension service. This trend could lead to a shift from old *dusuns*, which currently cover on average 3.0 ha of the individual holding in the different study sites, to new and young *dusuns* occupying on average 0.6 and 1.0 ha, respectively (Kaya, 1999). Although the average size of individually-owned farmland (= 5.3 ha) is much larger than for instance on Java (cf. Terra, 1958; Wiersum, 1982), yields from *dusuns* do not fully meet the subsistence needs of the people. Thus, lacking off-farm employment opportunities, sea-fishing is an important source of additional livelihood for *dusun* farmers (Kaya, 1999).

The *dusun* management on Saparua, practised since many generations, is an example for integrating a considerable number of tree species, many of them presumably components of the original vegetation, into sustainable land use systems on a small, resource-limited island. Thus, it may serve as an example for the suggestion of Janzen (1998) that only a 'gardenification of the tropics' is capable of preserving large lumps of wild biodiversity. However, the uncurbed population growth on Saparua will be a major challenge to the sustainability of this traditional land use system.

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