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Kebon tatangkalan: a disappearing agroforest in the Upper Citarum Watershed, West Java, Indonesia

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Abstract

A comprehensive study was carried out on a typical indigenous agroforestry system, called *kebon tatangkalan*, in the changing agricultural landscape of the Upper Citarum Watershed, West Java, Indonesia. The main objectives of the study are to elucidate the structural patterns, multidimensional functions, and dynamics of this multi-layered agroforest. The study has identified 12 groups of different plant assemblages indicating that this type of agroforest contributes considerably to the heterogeneity of the agricultural landscape in the study area. Multivariate analysis suggests that elevation and slope are the biophysical factors that correlate most significantly with the distribution of plant species in *kebon tatangkalan*. The presence of this man-made vegetation is currently declining from the landscape due to population growth and rapid regional economic development. Serious effort to revitalize this traditional agroforest is needed to prevent its disappearance. Introduction of highly productive species and establishment of integrated policies in regional land-use planning and management are measures that should be taken into account in preserving this traditional agroforestry system.

Introduction

Various forms of agroforestry have long been known in the local land-use systems of the Upper Citarum Watershed, West Java, Indonesia. An agroforestry system locally known as *kebon tatangkalan* or *bojong* is one of the most typical ones. This agroforestry system has been evolving under the influence of various biophysical and socioeconomic factors. Its physiognomic appearance is the most distinct among the existing agroecosystem components. Multi-layered vegetation patches of *kebon tatangkalan* scattered within the matrix of agricultural land has made the landscape of the Upper Citarum Watershed heterogeneous.

Even though the existence of *talun* has been acknowledged for more than a century (Christanty et al. 1996), studies on its biological as well as ecological features and also its dynamics have not been revealed thoroughly. Previous studies (e.g., Soemarwoto and Soemarwoto 1985; Christanty et al. 1996) only revealed that, basically, there are two major categories of *talun*, bamboo-dominated *talun* and mixed *talun*. To date, there is no data with regard to the variation of plant assemblages in these two categories. Yet, such data are important to assess whether these agroforestry systems contribute to biodiversity enrichment not only at species level, but also at community level.

It is presumed that *kebon tatangkalan* has long been playing a significant role in the entire production system of the agricultural landscape in the Upper Citarum Watershed. Moreover, from the standpoint of ecological function, the occurrence of patches of this agroforest type is very crucial for various wildlife, birds and insects in particular (Erawan et al., 1997). Apart from that, the multi-layered structure of vegetation and its rooting system has made this type of land-use very potential in the prevention of soil erosion.

Kebon tatangkalan in the Upper Citarum Watershed is currently under serious pressure from population growth, expansion of capital-intensive agriculture and industries. However, it is regrettable that the decline of this multi-layered agroforest has been overlooked by scientists, decision makers, and regional planners. Before 1970s, this man-made vegetation was believed to cover the agricultural landscape in the Upper Citarum Watershed in a very extensive area. But in the present time, patches of this land-use type can only be encountered in places not higher than 1250 meter Above Sea Level (ASL). Considering the multidimensional roles of this agroforest, its disappearance from the agricultural landscape of Citarum Watershed might cause significant effects on the entire environmental setting within the watershed.

Based on the above considerations, study that encompasses bio-ecological and socioeconomic aspects of *kebon tatangkalan* in the Upper Citarum Watershed, West Java Indonesia was carried out. This paper describes some results obtained from the study. The objectives of the paper are to describe structural as well as compositional aspects of *kebon tatangkalan* vegetation and its associated faunal diversity, and to elucidate the socioeconomic function and the dynamic of this agroforest.

Materials and methods

Study sites

The present study was undertaken in two villages with different agroclimatic zones, namely Wangisagara and Sukapura villages (located within 07° 04′ 00′ − 07° 10′ 30′ South and 107° 40′ 30′ − 107° 44′ 45′ East; 850 m − 1250 m ASL). In general, the topography of the study villages is flat to undulating, but in some parts of the villages, steep areas can also be encountered. Major land use types in the study villages are rice fields, upland fields (including *kebon tatangkalan* patches), and human settlement. The annual rainfall ranges from 1500 to 2500 mm. The mean daily minimum temperature is 25 °C and the mean daily maximum temperature is 30 °C. Despite the majority of its population working in the agricultural sector, landlessness in the two study villages is relatively high; not less than 40% of the households are landless.

Sampling and data collection

The study encompasses ecological and socioeconomic aspects of *kebon tatangkalan.* Ecological aspect covers structural and compositional patterns of vegetation in relation with faunal diversity. Floristic survey was carried out using sample plots; 148 plots were randomly selected in the two study villages. A unit of ownership was considered as one plot, and plant inventory was performed in each sampled plot. The presence and number of individuals of each species in each sample were recorded.

Avifauna and insects are considered as major taxa that have close relation with the presence of this type of agroforest in the Citarum Watershed. Avian survey was carried within these plots using Point Count technique (Bibby et al. 1992). Data regarding insect communities were derived from previous survey carried out in the same study villages. Flying insect inventory was carried out using sweeping net, whereas, pit-fall trap technique was used for soil surface insects (Southwood 1978).

Socioeconomic aspect included in the present study aimed to reveal social background of the owners and socioeconomic function of this type of agroforest. Socioeconomic survey was undertaken using questionnaires and semi-structured interviews (SSI). For interviews using questionnaires, a number of owners in the two study villages were randomly selected with a formula described in Lynch et al. (1974). The total number of owner selected as respondents was 77. A number of Key Informants (KIs) were purposively selected for SSI. The KIs were elderly people, head of the village, and villagers that depend on resources provided by *kebon tatangkalan*.

Data analysis

To indicate species dominance in *kebon tatangkalan* in the study area, Importance Value Indices (IVI) were calculated for each species. Each index was calculated based on the relative values of species density and its frequency. Multivariate analysis was performed to elucidate the relation between the distribution of trees and bamboos species in *kebon tatangkalan* and a complex of environmental variables (ter Braak et al. 1987). The measured variables were elevation, slope, area, light intensity, and shape. Apart from that, TWINSPAN analysis was performed to characterize species assemblages.

To elucidate the relation between complexity of vegetation structure and diversity of birds, correlation analysis was performed based on 31 *kebon tatangkalan* plots that were selected randomly. Socioeconomic data were analyzed using simple statistic calculations to summarize responses given by the respondents; the results are presented in percents.

Results

Structural and Compositional Patterns of kebon tatangkalan vegetation

Even though there is no official record with regard to the exact period of the first establishment of *kebon tatangkalan* in the Upper Citarum Watershed, some Key Informants believe that this land-use type has existed before 1900s. The presence of figs species (*Ficus* spp) with diameter at breast height more than 80 cm indicate that the establishment of this man-made vegetation is not recent. Inheritance system of *kebon tatangkalan* can also be used to indicate its long establishment in the Upper Citarum Watershed. 18.7% of respondents interviewed divulge that they inherit the land from their parents. Some of them become heir to this agroforest in 1920s or before. They mention that their parents inherited the land from the grandparents. Based on inventory carried out in the two study villages, the acreage of this land-use type as compared to the total area of the village is very small, only 2.8% and 4.9%, respectively. Nowadays, patches of *kebon tatangkalan* are commonly encountered in various sizes ranging between less than 0.5 ha and 10 ha.

The most dominant tree species between the two study villages are different. In Wangisagara village, located in the lower part, the dominant tree species other than bamboos are, among others, *Pithecelobium dulce* Benth, *Gnetum gnemon* L., *Arenga pinnata* (Wurmb) Merrill, and *Parkia speciosa* Hassk. In Sukapura village, the dominant species are *Eucalyptus alba* Reinw. ex Blume, *Albizia montana*, *Calliandra calothyrsus* Meisn., and *Euphorbia pulcherrima* Willd. ex Klotzch. Table 1, Table 2 summarize other species commonly found in the two study villages. In terms of species richness, a total number of 228 species of various growth forms are encountered in the 148 plots, but only 64 species belong to trees and bamboos categories. The mean densities of tree stand is about 1020 mature and young individuals per ha, whereas, bamboos is about 268 clumps per ha.

Ordination analysis indicates that *kebon tatangkalan* plots in higher elevation are usually located in sloppy areas (Table 3). Apart from that, the shape of this multi-layered agroforest in high elevation tends to be elongated following topographical contours. Elevation and slope are the measured biophysical factors that correlate most significantly with the distribution of plant species in *kebon tatangkalan* (Table 3). Some woody species are only found (planted) in higher elevation, for example, *Albizia montana*, *Calliandra calothyrsus*, *Pinus merkusii* Jungh., and *Eucalyptus alba* (in Figure 1, these species are located in the right-hand side of the ordination diagram).

In sloppy areas, some woody species commonly found are, among others, *Mangifera foetida* Lour., *Spathodea campanulata* L., *Acer laurinum* Hassk., *Pinus merkusii* Jungh., and *Gigantochloa atter* Hassk. Ordination diagram also indicates that in plots dominated by bamboos species, e.g., *Gigantochloa apus* (Schult & Schult), *G. verticillata* Willd, and *Bambusa vulgaris* Schrader ex Wendland, light intensity tend to be low. In contrast, light intensity is higher in mixed *kebon tatangkalan* where various fruit trees can be encountered (in Figure 1, these fruit tree species can be found in the left-hand side of the diagram).

TWINSPAN analysis indicates that all the species are clustered into 12 plant assemblages (Figure 2). The number of species in each plant assemblage varies between 8 and 41 species. This indicates that this type of land-use is not only diverse in terms of species and growth forms, but also it varies in terms of plant assemblages. Some species usually grow in forest area are also present in this man-made vegetation, among others, *Alsophylla glauca* (Blume) J.Smith, *Neonauclea lanceolata* Merr., *Acer laurinum* Hassk., *Piper aduncum* L., and *Macaranga tanarius* (L) Muell. Arg.

Diversity of faunas in kebon tatangkalan

Kebon tatangkalan as multi-layered agroforest and its diverse species composition is very important habitat for various organisms living in the agricultural land-

Table 1. Some dominant species (IVI > 5%), its main use and occurrence in *kebon tatangkalan* in Wangisagara village, West Java, Indonesia.

Botanical name	Local name	IVI (%)	Use	Occurrence
A. Trees				
Pithecelobium dulce Benth	Jengkol	23.34	Fr	P
Gnetum gnemon L	Tangkil	21.07	Fr	P
Arenga pinnata (Wurmb) Merrill	Aren	10.31	Fr/Sf/B	W
Parkia speciosa Hassk	Peuteuy	10.12	Fr/Fw	P
Artocarpus heterophyllus Lam	Nangka	9.38	Fr	P
Mangifera indica L	Buah	7.01	Fr	P
Carica papaya L	Gedang	6.80	Fr/Me	P
Persea americana Mill	Alpuket	6.47	Fr	P
Hibiscus similis Blume	Tisuk	6.32	Fw	P
Psidium guajava L	Jambu batu	5.43	Fr/Fw	P
B. Bamboos				
Gigantochloa apus Schult & Schult	Awi tali	72.49	C/Fw/Fe	P
Gigantochloa atter Hassk	Awi temen	51.73	C/Fw/Fe	P
Gigantochloa verticillata Willd	Awi ageung	48.51	C/Fw/Fe	P
Bambusa vulgaris Schrader ex Wendland	haur hejo	27.18	C/Fw/Fe	P
C. Shrubs				
Chromolaena odorata (L) RMKing&Hrob	Kirinyuh	24.91	Fw	W
Sida retusa Linn	Sadagori	16.43	N	W
Urena lobata	Pungpulutan	14.79	N	W
Glichenia linearis	Paku api	14.11	N	W
C. Non-graminoid herbs				
Eupatorium riparium Regel	Teklan	52.13	N	W
Ageratum conyzoides L	Babadotan	19.91	N	W
Oxalis corymbosa DC	Calincing	14.15	N	W
Alternanthera sessilis (L) RBr. ex DC	Gelang	7.49	N	W
Ipomoea batatas (L) Lam.	Hui boled	7.18	F/Fo	P
Musa paradisiaca L	Cau	6.46	Fr	P
Synedrella nudiflora (L) Gaertn	Jukut ibun	5.38	N	W

C = construction material; Fw = fuelwood; Fr = fruit; Fo = fodder; O= ornamental; B=beverage; Sf = sago flour; Fe = fence; F = food; Me = medicine; N = none; P = planted; W = wild.

scape, particularly birds and insects. In the present study villages, it was found that the majority of the 62 species of birds encountered during the study use *kebon tatangkalan* vegetation for perching, foraging, and nesting. The present study indicates that there is a tendency of more diverse bird species in more complex vegetation layering (Pearson's correlation = 0.47; significant at 0.01 level).

Furthermore, correlation analysis performed between the number of vegetation layers and different categories of avian community indicate that there is a tendency of higher diversity of insectivorous birds in more complex vegetation structure (Pearson's correlation = 0.45; significant at 0.05 level). But weak correlation is exhibited between the number of layers and the diversity of frugivorous birds (Pearson's correlation = 0.13). This result suggests that the multilayered agroforest in the Upper Citarum Watershed is a suitable habitat for various insects that are important for birds' prey.

The diversity of insects living in this type of agroforest is high, sixty-six families of flying insect are identified, and the diversity could be higher since particular families consist of more than one species. While, soil surface insects are less diverse; only 23 families are identified.

Socioeconomic functions of kebon tatangkalan

The ownership of *kebon tatangkalan* may reflect socioeconomic level of the owners. Inventory on land ownership indicates that 96% of owners interviewed

Table 2. Some dominant species (IVI > 5%), its main use and occurrence in *kebon tatangkalan* in Sukapura village, West Java, Indonesia.

Botanical name	Local name	IVI (%)	Use	Occurrence
A. Trees				
Eucalyptus alba Reinw ex Blume	Kalices	29.83	C/Fw	P
Albizzia montana	Selong montana	28.43	C/Fw	P
Calliandra calothyrsus Meisn.	Kalianra	25.37	Fw/Fo	P
Euphorbia pulcherrima Willd ex Klotzch	Kastuba	11.81	O	P
Coffea arabica L	Kopi	10.89	B	P
Arenga pinnata (Wurmb) Merrill	Aren	9.53	Fr/Fw/Sf/B	W
Artocarpus heterophyllus Lam	Nangka	8.80	Fr/Fw	P
Syzigum densifolia	Jambu	8.68	Fw	W
Toona sureni Merr.	Suren	7.68	C/Fw/Fo	P
Persea americana Mill.	Alpuket	6.83	Fr	P
Mangifera indica L	Buah	5.44	Fr	P
B. Bamboos				
Gigantochloa atter Hassk.	awi temen	74.90	C/Fw/Fe	P
Gigantochloa apus Schult&Schult	awi tali	67.26	C/Fw/Fe	P
Gigantochloa verticillata Willd	awi ageung	43.83	C/Fw/Fe	P
C. Shrubs				
Chromolaena odorata (L) RMKing&H.Rob	Kirinyuh	52.67	Fw	W
Sida retusa Linn.	Sadagori	51.14	N	W
Urena lobata	Pungpulutan	16.85	N	W
Cestrum nocturnum L.	Kembang dayang	14.46	Fe	P
D. Non-graminoid herbs				
Eupatorium riparium Regel	Teklan	63.27	N	W
Oxalis corymbosa DC	Calingcing	29.17	N	W
Ageratum conyzoides L	Babadotan	17.08	N	W
Alternanthera sessilis (L)RBr. Ex DC	Gelang	8.28	N	W
Ipomoea batatas (L) Lam	Hui boled	6.91	F	P
Musa paradisiaca L	Cau	6.87	Fr	P

C = construction material; Fw = fuelwood; Fr = fruit; Fo = fodder; O= ornamental; B=beverage; Sf = sago flour; Fe = fence; F = food; N = none; P = planted; W = wild.

Table 3. Canonical coefficients, intraset correlation coefficients for axes 1 and 2, and weighted correlation among variables in *kebon tatangkalan* in the Upper Citarum Watershed (only for woody species).

Variable	Canonical Coeff.		Intraset Corr.		Matrix of correlation among variables				
	Axis 1	Axis 2	Axis 1	Axis 2	Elevation	Slope	Light	Area	Shape
Elevation	*0.979*	0.602	*0.990*	0.121	–	0.401	− 0.485	0.067	0.489
Slope	0.141	*-0.997*	0.408	*-0.880*		–	− 0.206	0.168	0.313
Light intensity	0.006	0.075	− 0.511	0.064			–	0.026	− 0.229
Area	− 0.038	0.111	0.033	0.024				–	0.126
Shape	− 0.043	− 0.297	0.521	− 0.143					–

in the present study possess rice field and/or vegetable gardens, other than *kebon tatangkalan* land. Some owners possess one to three hectares of agricultural land, while the average of land ownership in the present study area is not more than 0.2 ha. Higher economic status can also be indicated by the fact that 75.3% of owners acquire *kebon tatangkalan* land by purchasing from other villagers. This suggests that in spite of elevating price of agricultural land due to its limited availability, they still possess enough cash to purchase land.

All respondents mention that prior to the expansion of input-intensive agriculture practices in the late 1970s and when the demand for bamboos and other

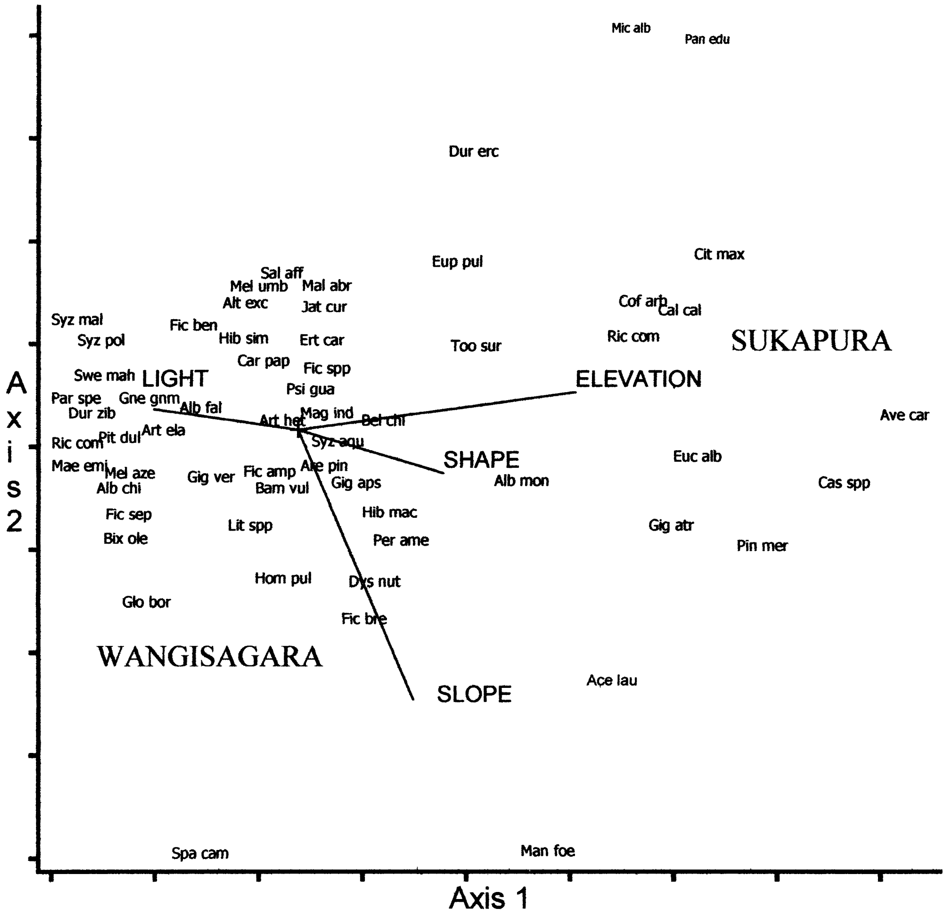

Figure 1. Biplot of CCA ordination diagram of woody species and some environmental variables in *kebon tatangkalan* in the Upper Citarum Watershed, West Java, Indonesia; species names are abbreviated (see Appendix for full scientific names).

timber used for various purposes were substantial, *kebon tatangkalan* was an important source of income. But this is no longer the case in the present time; none of the owners rely on this traditional system as their main source of income. All respondents point out that they rely more on rice and/or vegetable cultivation as family income.

Despite decreased production, all owners admit that in the present time the price of particular *kebon tatangkalan* product, particularly bamboos and timber, is higher than in five years ago. The current price of one bamboo varies between Indonesian Rupiah (IDR) 5,000 and IDR 8,000, or approximately US$ 0.6 – US$ 0.9 (US$1 = IDR 8,900, January 2003), depending on the kind (species) of bamboo. While, the price of one mahogany (*Swietenia mahagoni* (L) Jacq.) tree, with trunk diameter about 50 cm, is approximately US$11.23. The price of a 6-year-old tree of *Albizia falcata* −one of the commonest introduced tree species− with trunk diameter about 20 cm is between US$ 4.50 and US$ 5.60. In the last five years, *Albizia* woodlots tend to expand gradually due to its characteristic as fast growing species, therefore, the owners are more attracted to grow this species and also due to its higher market demand.

In the present time, the productive function of *kebon tatangkalan* is only to support subsistence need in fruit and vegetable consumption. Inventory carried out in the present study indicate that there are about 16 fruit-producing tree species found in all sampled plots. Fruit tree species such as *Artocarpus heterophyllus* Lam. (jackfruit), *Psidium guajava* L. (guava), *Mangifera indica* L. (mango), and *Persea americana* Mill. (avocado) were among the most commonly planted in this agroforest. But nowadays, their subsistence role seems to be diminishing. The owners,

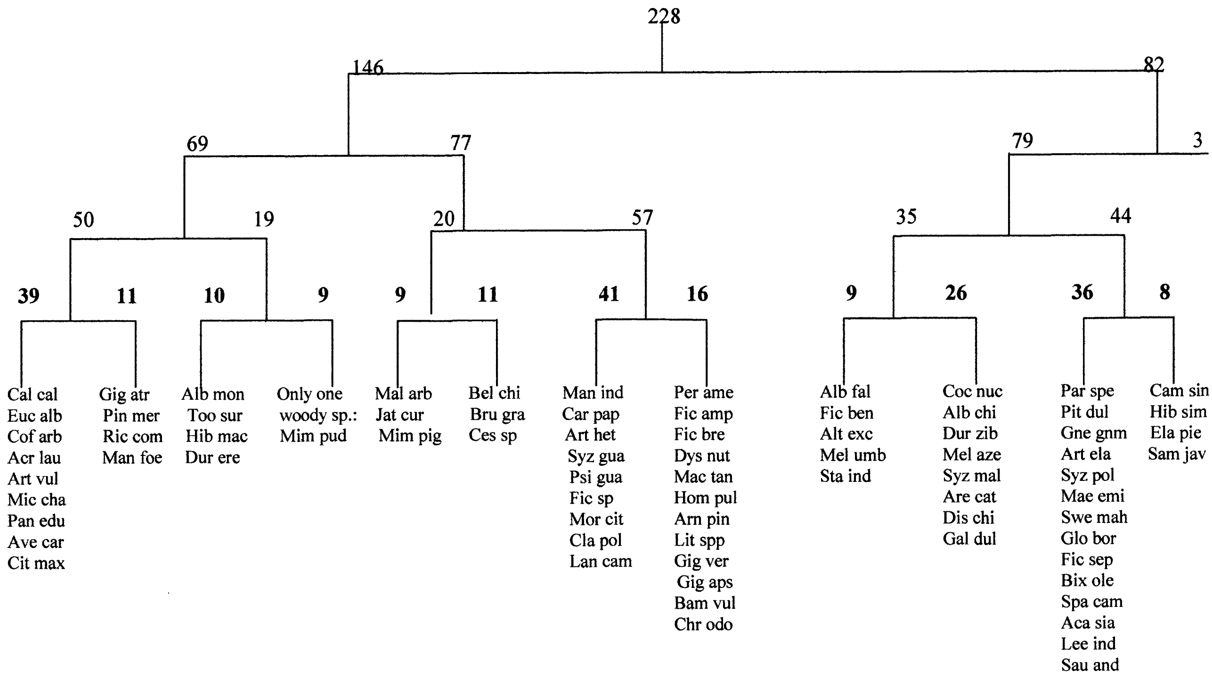

Figure 2. Floristic classification (TWINSPAN) for 148 plots of *kebon tatangkalan* in the Upper Citarum Watershed, West Java, Indonesia; numbers in the dendogram indicate the number of plant species belonging to each group (only woody and bamboos species are listed; species names are abbreviated).

for various reasons, infrequently carry out replanting new fruit trees. The study reveals that no more than 20% of respondents still perform tree planting in the last five years. More than 60% of the respondents reveal that constraint in marketing the product and thievery are among the main reasons that make them reluctant in replanting new seeds.

Almost all of the owners reveal that *kebon tatangkalan* in the present time is a valuable asset merely from the point of view of the land rather than the products it produces. They admit that very limited land available in the Upper Citarum region makes the price of land very expensive. The price of one *tumbak* (local term which is equivalent with 14 m^2) of land in Sukapura village, for example, could be as high as IDR 400,000 (approximately US$ 44.90). Therefore, most of the owners consider the land as a kind of saving that can be sold in case they need some cash. Some owners rent their *kebon tatangkalan* land in order to improve its economic function.

Despite its decreasing productive function for household economy, *kebon tatangkalan* still has social function. This multi-layered agroforest has been an important part in inheritance system for generations. The parents usually inherit the land to their descendants. Almost all respondents admit that owner will not sell this asset unless emergency situation occurs, e.g., big cash is needed for 'Hajj' pilgrimage.

Another social function of this land-use type is in fuelwood fulfillment, particularly for poor villagers. There are various plants growing in this multi-layered agroforest that can be used as fuelwood (see Table 1, Table 2). All the interviewed owners state that they usually allow other villagers to use their land as source of fuelwood as long as no tree is cut. Field observation confirms that in villages located far from forested lands, this multi-layered agroforest is the most important source of fuelwood for poor villagers.

The dynamics of kebon tatangkalan and its affecting factors

All Key Informants argue that expansion of intensive agriculture affects the existence of *kebon tatangkalan*. Nowadays, intensive agricultural land, small- as well as large-scale industrial areas, and human settlement cover no less than 80% of the total area of the upper part of Citarum Watershed (approximately 2,000 km^2). All respondents also point out that continuing population growth is another factor that causes conversion of the existing agricultural land, including *kebon tatangkalan*.

According to respondents, the occurring land-use change is aimed to accommodate economic improvement efforts. This has caused less productive land-use type to diminish from the landscape of the Upper Citarum Watershed. *Kebon tatangkalan* is among the most affected in the dynamics of land-use change in this area. Unfortunately, none of the respondents can estimate the annual conversion rate of this agroforest to other land-use types. However, the tendency of decreasing number of owners can be used as indicator of the decreasing area of *kebon tatangkalan*.

The present study reveals that the number of owners that have this traditional agroforest land with acreage larger than 400 m^2 is lessening. The number of owners decreases slightly compared to inventory carried out in 1995. In Sukapura village, there were 58 households owned *kebon tatangkalan* in 1995, and it decreases to 47 households in year 2000. Similarly, the number of owners also decreases in Wangisagara, from 105 households in 1995 to 100 households in year 2000. Based on the inventory, the present total number of households in these two villages (about 2600 households) that own *kebon tatangkalan* is only about 2.5%.

Field observations carried out between 1995 and 2000 in higher elevation area (above 1000m ASL) indicate that many *kebon tatangkalan* patches have been converted to a more productive agricultural land like cash crop fields. In this area, climatic and edaphic conditions are more suitable for farmers to grow annual crops such as potatoes, cabbage, green onion, and carrots. Interviews with some owners suggest that if farmer converts one-*patok* (approximately 400 m^2) *kebon tatangkalan* to be planted with carrots, he could earn at least IDR 75,000 (about US$ 8.80) within 70 days. In comparison, he has to wait for at least five years in order to log the planted timber (*Albizia* or *Eucalyptus*) to gain the same amount of cash.

The ongoing decline of *kebon tatangkalan* has resulted in greater effort carried out by fuelwood users to collect adequate amount of fuelwood. Nearly 50% of fuelwood user respondents reveal that nowadays they have to spend more time to gather fuelwood from this agroforest. They argue that to collect adequate amount of fuelwood for daily need they have to go from one place to another as patches of this agroforest are becoming more fragmented in the agricultural landscape of Citarum Watershed.

Discussions and conclusions

Structural patterns of kebon tatangkalan and comparison with other forest gardens

The biological features of *kebon tatangkalan* exhibits similarities with an agroforest type, called *talun*, found in Soreang district− also located in the Citarum Watershed (Christanty et al. 1996). Various tree and bamboo species are common to both areas, among others, *Arenga pinnata*, *Parkia speciosa*, *Mangifera indica*, *Albizia falcata*. The four bamboo species found in the present study sites are also very common in *talun* vegetation. Bamboos appear to be an important component because they are always present in every patch of this agroforest in both areas. Specific term 'talun awi' (meaning bamboo *talun*) is popular among farmers in Soreang district, but not in the present study area.

Despite its similarity, there is to some extent a difference between the two areas in terms of management of this man-made vegetation. A variation of *talun* system, called *talun-kebun* rotation cycle, is commonly practiced by farmers in Soreang district. As described by Mailly et al. (1997), the cycle consists of one year of mixed species vegetable cropping, followed by a year of cassava cropping, and four years of bamboo fallow, this makes the total cycle length of six years. In the present study area, a mixture of perennial plants and annual crops can also be encountered in some *kebon tatangkalan* patches. But this mixture is not a *talun-kebun* system because no rotation system is intended by the farmers.

Compositional feature of *kebon tatangkalan* also demonstrates similarity with multistoried village garden found in Bogor area, also located in the Province of West Java. Various trees occupying main canopies of *kebon tatangkalan* such as *Pithecelobium*, *Parkia*, *Mangifera*, *Artocarpus*, *Arenga*, *Gnetum*, and bamboos are also common in this type of village garden (Michon and Mary, 1994). Compositional similarity between the two systems also occurs in undergrowth shrubs such as *Sauropus androgynus*, *Claoxylon polot*, *Phylllanthus niruri*, *Glochidion borneense*, and some species belonging to Asteraceae and Verbenaceae.

Nevertheless, *kebon tatangkalan* has less number of species compared to multistoried village garden in Bogor. Michon and Mary (1994) point out that common garden plots, 300 to 500 m^2 in area, may contain more than 50 different tree and herb species. In *kebon tatangkalan* with approximately the same area as that in the village garden in Bogor, the number of species is not more than 40 (the range is between 12 and 40; with average 23.9 ± 7.1). Similar condition is also true for tree density, in which village garden in Bogor has higher mean density of mature and young trees than *kebon tatangkalan*.

It is quite interesting that *kebon tatangkalan* shares some common species with another typical forest garden, called *dusun*, in Central Maluku (Kaya et al. 2002). Yet, the two sites are separated by a distance of not less than 2000 km. Among these common species are *Mangifera indica* Blume, *Cocos nucifera* Linn, *Syzygium aromaticum (L.)* Merr, *Durio zibethinus* Moon, *Toona sureni* Merrill, and *Arenga pinnata* Merrill. This suggests that these species are important components of multi-layered agroforest in Indonesia since a long time ago. Despite this, both systems have different origin of initial establishment. The *dusun* was initially established with the cutting of a patch of pristine forest, but fruit trees are usually left uncut (Kaya et al. 2002). Furthermore, the starting point of *dusun* is the establishment of a clove or coconut plantation in open areas. The initial establishment of *kebon tatangkalan* was undertaken by planting any useful species of trees and bamboos in privately owned land.

The existence of *kebon tatangkalan* in the Upper Citarum Watershed represents the evolutionary development of local knowledge in the formation of artificial vegetation. The owners are able to combine their preference and the abiotic conditions, which can be seen from the result of ordination analysis. The owners living in different agroclimatic zones are able to characterize species suitable to grow in that area. On the other hand, they also acknowledge the importance of tree planting in sloppy area.

General classification described in Christanty et al. (1996) only mentioned two different types of *kebon tatangkalan* (*talun*) commonly found in West Java, i.e., mixed *talun* and bamboo-dominated *talun*. The present study has identified twelve different plant assemblages in *kebon tatangkalan*. The occurrence of these variations suggests that this agroforest type contributes to the heterogeneity of the agricultural landscape in the Upper Citarum Watershed.

Apart from high variation in plant assemblages (communities), *kebon tatangkalan* patches in the study area also exhibit high species variability as indicated by low values of Sorensen's Similarity Index (Parikesit et al. 1997) between paired samples. This suggests that variation of the overall species composition among patches is apparent. High species variability also suggests that resemblance on species preference among owners only occurs for particular species such as the four species of bamboos, *Artocarpus heterophyllus*, *Pithecelobium dulce*, and *Gnetum gnemon*. On the other hand, variation of microclimatic condition under the main canopy in different patches is likely key factor resulted in high species variability in the agroforest.

Vandermeer et al. (1998) emphasized two distinct components of biodiversity in agroecosystem perspective, called 'planned diversity' and 'associated diversity', both are relevant in the context of *kebon tatangkalan*. Owners' decision with regard to species planted in their land is based on their preference and different purpose of uses such as for timber and construction materials, fuelwood, subsistence foods, and prevention of soil erosion. This has resulted in high planned diversity in this agroforest. On the other hand, unintensive maintenance of this agroforest type has resulted in the presence of various unplanted plant species with different life forms that eventually creates more complex vegetation structure. This kind of structure generates suitable habitat for numerous faunas like insects and birds. The presence of numerous unplanted plants, birds, and insects is the associated diversity in *kebon tatangkalan*.

At larger scale, the presence of the multi-layered agroforest with its variation of plant assemblages in the agricultural landscape of the Upper Citarum Watershed makes the landscape structure heterogeneous. Overall, this is very important in maintaining biodiversity condition and soil conservation in the course of continuous changes of the landscape due to human disturbance. Previous study indicated that the rate of relative erosion situation in this agroforest was much less, only a half than that in upland fields planted with cassava or rice (Institute of Ecology, 1981).

Socioeconomic perspectives of kebon tatangkalan and the impacts of its conversion

It is likely that the current economic function of the products from *kebon tatangkalan* is not as important as that in some other forest garden systems. In 'tembawang' system in West Kalimantan, for example, selective weedings is performed during harvest season to facilitate fruit collection and also to maintain seedlings and saplings of valuable species. The income earned by many families throughout the month-long season was substantial (Padoch and Peters 1994). No such management practice is common in *kebon tatangkalan* system; none of the owners perform weeding or other agricultural practices aimed to obtain good fruit harvest.

The productive function of *kebon tatangkalan* that still can be found relates to vegetable consumption. Leaves and inflorescence of some species supply vegetable to villagers as part of their daily diet. Among these species are *Gnetum gnemon*, *Sauropus androgynus*, *Claoxylon polot*, *Xanthosoma* sp., and *Manihot esculenta*. These same species are also present in village gardens in Bogor area and they make up about 70% of vegetation supply for local villagers (Michon ands Mary 1994). But, different with that in village gardens, villagers in the Upper Citarum Watershed do not consume shoots of some bamboo species (*Gigantochloa apus*, *G. verticillata*, and *G. ater*). Similarly, use of bamboo shoots for commercial purpose is also absent. All respondents are not familiar with bamboo shoots market, although they acknowledge that there is a potent demand for this product. Bamboos are grown mainly for building materials such as for house floor and wall, animal shelter, irrigation pipes, bridges, and to make poles to attach legume vines.

For many villagers, the presence of multi-layered agroforest in the Upper Citarum Watershed cannot be neglected. Recent study (Parikesit et al. 2001) revealed that this multi-layered agroforest is the most important source of fuelwood for poor people living in villages far from forested area. About 51% of the respondents used fuelwood for daily cooking, in which 88% of the fuelwood users used *kebon tatangkalan* as their source of fuelwood. Therefore, if this main source totally disappears from the agricultural landscape of the Upper Citarum Watershed, the supply of 'free energy' from agroecosystem that has been taking place for decades will come to an end.

Conversion or simplification of vegetation structure (e.g., through woodlot establishment) of *kebon tatangkalan* is believed to provide the owners with higher economic gain. Cultivation of annual cash crops through input-intensive agricultural practices to replace traditionally managed agroforest has resulted in considerable increase of economic output. Nonetheless, whether the gain from cash crop cultivation is sustainable in a broader sense should be questioned. The detrimental effect of modern agriculture in various parts of the world's ecosystems, including the extensively practiced conventional monoculture systems, is widely recognized (e.g., Giller et al. 1997; Sotherton 1998; Kammerbauer and Ardon 1999).

Overall, conversion of this multi-strata agroforest at the landscape level will reduce spatial heterogeneity. It is also important to point out that the conversion might cause habitat loss for various faunas living in this complex man-made vegetation. This ultimately would affect the integrity of the entire ecosystem within the landscape of Citarum Watershed.

It is obvious that the decline of this long time known agroforest is due to its decreasing role in generating significant income to the owners. Therefore, maintenance of this traditional agroforest should be undertaken through revitalization effort. To encourage the owners to maintain their *kebon tatangkalan*, an incentive in the form of free seedling assistance should be considered. This is in concordance with their expectation that government or any development agency working in rural development should provide them with high quality fruit trees that have good market demand. However, it should be pointed out that revitalization should not put too much emphasis on the perspective of the economic function. In concordance with the goal of agroforestry development, it has to take into account any relevant ecological consideration.

Above all, the decline of *kebon tatangkalan* is a consequence of lack of policy and institutional support to maintain this complex man-made vegetation. The present policy in land-use planning and conservation established by the West Java Provincial Board of Planning and Development does not address specifically for the maintenance of this ecologically important land-use. On the other hand, conservation effort is likely to be confined in more natural ecosystem such as the remnant forest in mountainous areas.

Constraints and prospects of maintaining kebon tatangkalan in the changing agricultural landscape

Vandermeer et al. (1998) point out that in multi-species systems, human dimension makes the problem more complicated because its indicators have more dynamic character than biophysical ones. Apart from that, future sociopolitical aspect has to be taken into consideration as well in carrying out evaluation of the current land-use options. The above statement suggests that effort to halt the decline of *kebon tatangkalan* will certainly have considerable constraints. To convince farmers that complex agroforest and its economic benefit are more advantageous in the long-term than agricultural practice that has maximum but short-term profit is not a simple task. It is also a great challenge for agroforestry advocates to persuade farmers that continuing expansion of capital-intensive agriculture that leads to the homogenization of land-use type will ultimately cause ecosystem instability.

The custom of tree growing practiced for more than a century by the local people is in fact a crucial 'capital' for the preservation of this multi-layered agroforest. Apart from that, there is an old tradition among the owners that this traditional agroforest is a family asset and it is a part of their inheritance system. On the other hand, climatic and edaphic conditions of the area are suitable for various tree species to grow. The introduction of new and high productive species should be encouraged since the present study revealed that in the study area the so-called 'Cinderella' species (Leakey and Newton 1994; cited in Nair 1998) is almost non-existent. There are various species from other regions that can be introduced such as *Artocarpus champedens* L, *A. communis* Forst., *Anacardium occidentale* L, *Achras sapota* (Gilly) Lundell, and *Nephelium lapaceum* L.

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Appendix

Table A1. List abbreviation and full scientific names of tree, bamboos, and other woody species in *kebon tatangkalan* in the study area.

Per ame	*Persea Americana*
Mag ind	*Mangifera indica*
Car pap	*Carica papaya*
Ert cars	*Erythrina carssifolia*
Art ela	*Artocarpus elasticus*
Art het	*Artocarpus heterophyllus*
Gig ver	*Gigantchloa verticilata*
Gig apus	*Gigantchloa apus*
Gig ater	*Gigantchloa atter*
Cal cal	*Calliandra calothyrsus*
Euc alba	*Eucalyptus alba*
Pin mer	*Pinus merkusii*
Alb mon	*Albizia montana*
Too sur	*Toona sureni*
Hib mac	*Hibiscus macrophyllus*
Hib sim	*Hibiscus similis*
Cam sin	*Camelia sinensis*
Cof arb	*Coffea arabica*
Dur ere	*Duranta erecta*
Eup pul	*Euphorbia pulcherrima*
Mal arb	*Malvaviscus arboreus*
Are pin	*Arenga pinnata*
Fic amp	*Ficus ampelas*
Acr lau	*Acer laurinum*
Syz aqu	*Syzygium aqueum*
Psi gua	*Psidium guajava*
Ala chi	*Alangium chinensis*
Mac tan	*Macaranga tanarius*
Ric com	*Ricinus communis*
Fic brev	*Ficus brevicuspis*
Fic spp	*Ficus sp*
Jat cur	*Jatropha curcas*
Bam vul	*Bambusa vulgaris*
Mic alb	*Michelia alba*
Man foe	*Mangifera foetida*
Syz den	*Syzigium densifolia*
Lit sp	*Litsea sp*
Alb fal	*Albizia falcata*
Cit max	*Citrus maximus*
Mim pud	*Mimosa pudica*
Mim pig	*Mimosa pigra*
Pan edu	*Pangium edule*
Mor cit	*Morinda citrifolia*
Mel umb	*Melochia umbellata*
Mel aze	*Melia azedarach*
Hib mac	*Hibiscus macrophyllus*
Cla pol	*Claoxylon polot*
Lan cam	*Lantana camara*
Chr odo	*Chromolaena odorata*
Coc nuc	*Cocos nucifera*
Ela pie	*Elaeocarpus pierrei*
Sam java	*Sambucus javanicus*
Glo bor	*Glochidion borneense*
Bix ole	*Bixa olerana*
Sau and	*Sauropus androgynus*
Spa cam	*Spathodea campanulata*
Aca sia	*Acasia siamea*
Lea ind	*Lea indica*
Gal dul	*Garcinia dulcis*
Bel chi	*Belamcamda chinensis*
Dys nut	*Dysoxylum nutans*
Hom pul	*Homalanthus pulponeus*
Fic sep	*Ficus septica*
Fic ben	*Ficus benyamina*
Alb chi	*Albizia chinensis*
Dis chi	*Disporium chinensis*
Gne gnm	*Gnetum gnemon*

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