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Socio-ecological dimensions of agroforestry called *kebun campuran* in tropical karst ecosystem of West Java, Indonesia

PARIKESIT[1,2,3], SUSANTI WITHANINGSIH[1,2,3,♥], FAKHRUR ROZI[1,2]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 45363, West Java, Indonesia. Tel.: +62-22-7796412, ext. 104, Fax.: +62-22-7795545. ♥email: susanti.withaningsih@unpad.ac.id.
[2]Center for Environment & Sustainability Science, Universitas Padjadjaran. Jl. Sekeloa Selatan I, Bandung 40213, West Java, Indonesia
[3]Graduate School of Environmental Sciences & Sustainability Science, Universitas Padjadjaran. Jl. Dipatiukur No. 35, Bandung 40132, West Java Indonesia

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Abstract. *Parikesit, Withaningsih S, Rozi F. 2021. Socio-ecological dimensions of agroforestry called* kebun campuran *in tropical karst ecosystem of West Java, Indonesia. Biodiversitas 22: 122-131.* Traditional and modernized systems combining agricultural and forestry production systems-called agroforestry-was developed by humans under the influence of biophysical and social conditions which often result in heterogeneous landscape. The so-called *kebun campuran* (mixed gardens) is one of the agroforestry forms that can be encountered in the humid tropics of Indonesia. However, socio-ecological information of this man-made vegetation and its multidimensional functions in particular environmental settings like karst is still limited. This paper aims to elucidate socio-ecological dimensions of *kebun campuran* in karst ecosystem in Pangandaran District, West Java, Indonesia. A vegetation survey was carried out to reveal the bio-ecological dimensions of *kebun campuran* complemented with socio-economic questionnaires. The results show that *kebun campuran* played an important role for the owners as the majority of them gained economic benefits from this agroforest. More than 50% of the owners had their main income from *kebun campuran*, therefore, *kebun campuran* was considered a valuable family asset. *Kebun campuran* ownership put the owner in a higher social status, despite the fact that 80.9% of them had only elementary education background. Correlation analysis showed that there was a very significant correlation between the areas of *kebun campuran*, rice-field, and homegarden ownership. The analysis also indicated that the economic value of *kebun campuran* derived from its products increased as its area became larger. There were diverse products like timber, fruits, fuelwood and forages extracted from *kebun campuran*. Among economically important species were *Albizia chinensis* (silk tree), *Cocos nucifera* (coconuts), *Manilkara zapota* (sapodilla), *Musa paradisiaca* (banana). Despite its beneficial value, *kebun campuran* was not intensively managed. On the other hand, the structural vegetation pattern of *kebun campuran* was the result of various practices carried out by the owners through the processes of introduction, domestication, and selection of plant species. Maintaining *kebun campuran* in the coastal landscape of Pangandaran might ensure the future of karst ecosystem in this southern coastal area of West Java.

Keywords: Pangandaran, sustainability, tourism, vegetation structure

INTRODUCTION

The launch of the Sustainable Development Goals (SDGs) in 2015 did not necessarily address the development of agroforestry, which are prevalent for centuries, and all the problems related to agroforestry management and practices became outdated. Of the 17 objectives listed in the SDGs, some of them are directly and indirectly related to agroforestry (Leimona and van Noordwijk 2017; Montagnini and Metzel 2017). Issues of poverty, famine, climate change, food security and sovereignty, biodiversity, conservation of land and water resources, and renewable energy (biomass) are also the focus of agroforestry. Therefore, suffice it to say that the development of agroforestry will never be out-of-date as long as human being continues to depend on the very basic natural resources such as food, land and water resources, and the diversity of life that is complementary to meeting the needs and welfare of human life. Agroforestry is a sustainable practice based on the principle of 'think globally, act locally' in dealing with various environmental problems that increasingly threaten human survival. One of the practical implementations of this foundation is tree-planting activity on a local scale in order to mitigate global threats under climate change phenomenon (Tschora and Cherubini 2020).

The development of agroforestry occurred with the local practices of early man in various parts of the world, especially in the tropics, which then became a global interest that was increasingly relevant because of its sustainability from local to global scale. As a practice that began from a local scale in order to deal with global issues, the characteristics of agroforestry practices are strongly influenced by aspects of social and biophysical localities (Sood and Mitchell 2009). It is not surprising, therefore, that the practice of agroforestry in Indonesia is rich with local terminologies, for example in terms of local names based on plant compositions, vegetation structures, management practices, and the overall agroforestry system developed in some places. In West Java, for example, some local names are *talun*, *kebon tatangkalan/ kebon kai*, *kebon awi*, *kebon campuran*, and *bojong* (Christanty et al. 1996; Parikesit et al. 2005). In Tapanuli, North Sumatra, the terms *'kobun pocal*' and '*tombak haminjon'* are used for a

type of mixed local garden (Martini et al. 2010). In West Kalimantan, a well-known and still practiced agroforestry system is '*tembawang*' (Yuwariah 2016).

Empirical evidence shows that agroforestry systems developed in Indonesia and in various other countries have various roles for the local communities. This system even provides benefits indirectly for people who live far from places where agroforestry practices are carried out. On a regional or watershed scale, the existence of agroforestry with its dense vegetation cover resembling a forest structure has an important role in maintaining the hydrological function of an area. From social perspective, agroforestry with its variety of management practices has long been believed to have the ability to alleviate the problem of poverty in rural communities. Additionally, the role of agroforestry in overcoming land-hunger problems, as well as its role in overcoming land degradation (Cooper et al. 1996; Mwase et al. 2015) and water shortage (Ong et al. 2006) due to over-exploitation, has been recognized as very effective. Similarly, the role of agroforestry in biodiversity conservation has been established in various studies (Parikesit et al. 2012). It is not surprising, therefore, that the practice of agroforestry is still recognized as an effective way of dealing with environmental crises impacting the social life and ecological conditions of people living in rural areas.

However, although agroforestry system is still considered effective in overcoming various social and environmental problems especially in rural areas, this system is facing an increasingly serious threat. In many rural areas in Indonesia agroforestry vegetation cover has been experiencing decline, and in some areas, it has even completely disappeared from local agricultural landscape. Unfortunately, there is no official data showing how much agroforestry area in various regions in Indonesia has been lost in the last few decades. Taking an example of the area of Citarum watershed in the 1970s, qualitatively it was shown that agroforestry vegetation locally known as *kebon tatangkalan* and *kebon awi* could be found to form an expanse of vegetation from 400m up to 1200m above sea level (Parikesit et al. 2005). However, the agroforestry vegetation in this region now consists only of fragmented patches, especially in sloping areas which is a result of intensification of agricultural systems, population growth, expansion of industrial areas, and human settlements. Necessary measures to maintain agroforestry systems in an agricultural landscape need to be carried out through revitalizing its economic functions so that other functions such as in social and ecological aspects could be promoted.

One type of agroforestry system that can still be found in various regions in Indonesia, especially in West Java, is *kebun campuran* (mixed gardens). Study on this type of agroforestry has been carried out in several regions (Christanty et al. 1996; Mailly et al. 1997; Widiarti and Prajadinata 2008), but there are not many publications on *kebun campuran* that develops in karst ecosystem setting. To date, there is no accurate information about the distribution of *kebun campuran* in this type of ecosystem, especially in coastal areas, despite the fact that studies in this subject can become appealing because of the role of agroforestry in this type of unique socio-ecological backdrop. The presence of *kebun campuran* is believed to be essential for the maintenance of productivity and integrity of the coastal landscape amidst the pressure of various sectors of development such as infrastructure, tourism, intensive agriculture, and settlements.

This paper describes *kebun campuran* as one of agroforestry practices found in the coastal area of southern West Java, specifically in karst ecosystem-dominated Pangandaran District that is currently known as one of the international tourism destinations. This article discusses the socio-ecological dimensions of *kebun campuran* and its management by local communities.

MATERIALS AND METHODS

Study area

The site is located at the coordinates of 7^0 42'0 "-7^0 44'24 " and $108^0$25'12 '-108^0 27'36', which includes seven *dusun* (sub-villages/hamlets), namely Tenjolaya, Margaluyu, Bugel, Bantarkawung, Karangpaci, Merjan, and Cibuluh of Kertayasa Village, Cijulang Sub-district, Pangandaran District, West Java Province, Indonesia (Figure 1). These *dusuns* are among the areas with extensive *kebun campuran* vegetation cover with the most number of owners. During the field surveys, census of *kebun campuran* owners and survey using structured questionnaires were undertaken.

Procedures

The number of *kebun campuran* owners based on census were 1,278 persons. The selection of *kebun campuran* owners as respondents was carried out using the formulae provided by Lynch et al. (1974):

Based on the above formula, 89 *kebun campuran* owners were chosen randomly as respondents and then the number of respondents was distributed proportionally to seven villages (Table 1).

Table 1. The distribution of the number of respondents in seven villages of the study area, Kertayasa Village, Cijulang Sub-district, Pangandaran District, West Java Province, Indonesia

Village name	Number of owners	Number of samples
Tenjolaya	262	19
Margaluyu	89	6
Bugel	272	19
Bantar kawung	185	13
Karangpaci	236	16
Merjan	114	8
Cibuluh	120	8
Total	1278	89

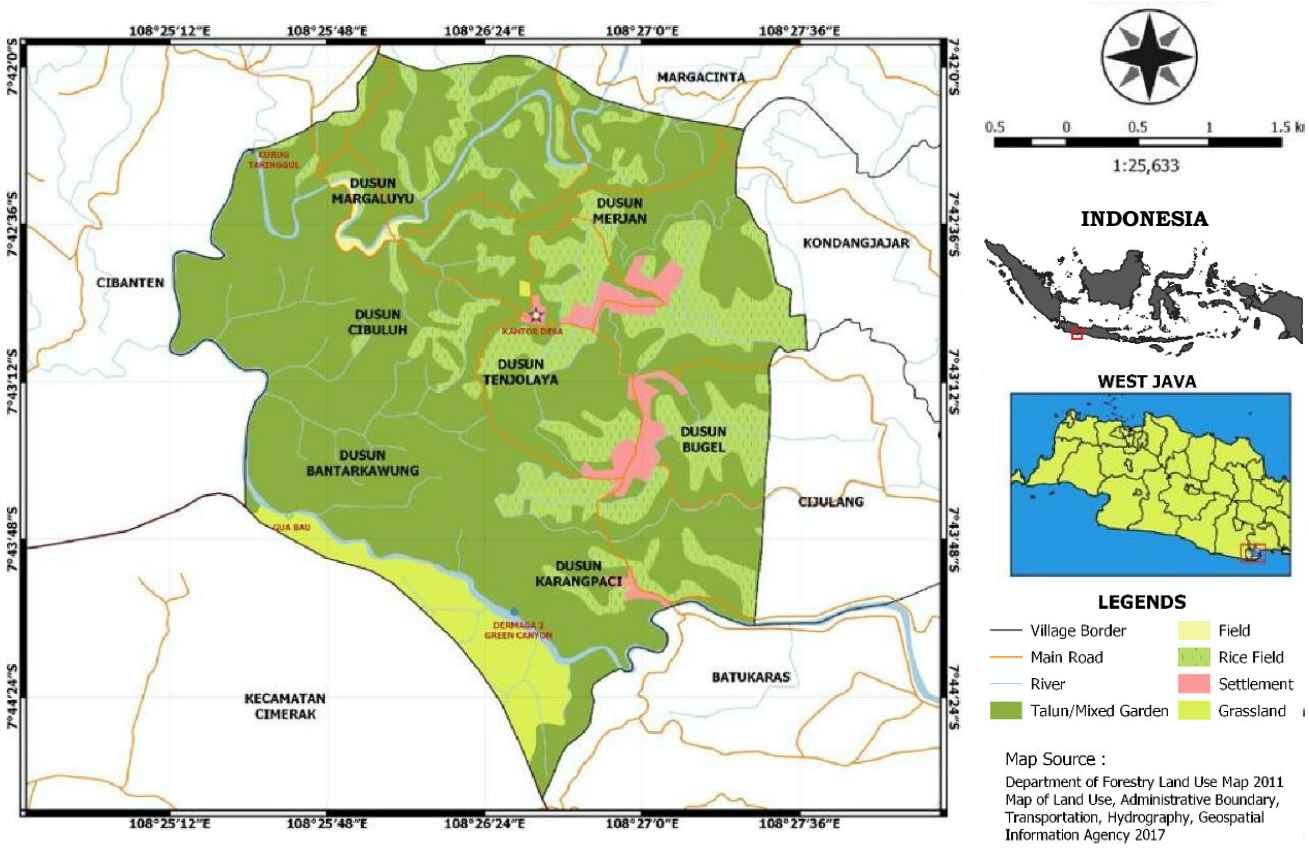

Figure 1. Map of the study area in Kertayasa Village, Cijulang Sub-district, Pangandaran District, West Java Province, Indonesia

The social survey included the profiles of *kebun campuran* owners, the ownership of land use other than *kebun campuran*, the methods of obtaining *kebun campuran*, the social and economic functions of *kebun campuran*, and the management of *kebun campuran*. Vegetation survey was carried out to reveal the composition and structure of *kebun campuran* vegetation. The data included the size of *kebun campuran*, the inventory of plant species, the number of individuals per species, and the stem diameter at breast height.

Data were analyzed using simple statistical calculations like the percentage of native and migrant owners, educational levels, permanent and non-permanent house possession, and possession of other land uses to describe the socio-economic profile of *kebun campuran* owners, while correlational analysis was intended to measure the relation within social and biophysical variables, and between social and biophysical variables. Vegetation data were analyzed to obtain Importance Value Index (IVI) from all species found in the plot samples. IVI indicates the 'position' of each species in *kebun campuran* community. The higher the IVI of a species the more important (ecologically) the existence of that species in *kebun campuran* vegetation.

RESULTS AND DISCUSSION

The social dimensions of kebun campuran

Profile of kebun campuran owners

As can be seen in Table 2, the majority (84.3%) of *kebun campuran* owners in the study sites were native people who had owned *kebun campuran* from generation to generation. Only a small proportion of *kebun campuran* owners were migrants; 50% of them had lived in the study sites for more than 30 years.

Although the majority of *kebun campuran* owners had only elementary education, they were the residents with a good socio-economic status. A fascinating outlook was that even to date, some of the *kebun campuran* owners did not view higher education with high regard. They reasoned that without higher education they could still support the family through livelihood supported by bioresources derived from *kebun campuran*.

The majority (80.9%) of *kebun campuran* owners had permanent houses (with cemented walls, tiled floors, and tiled roofs), only a small percentage (4.5%) had non-permanent houses (woven bamboo walls and cemented floors). Fifty-four percent of *kebun campuran* owners had a homegarden with an area of > 200 m^2, and some had > 1000 m^2. Other assets owned by the *kebun campuran* owners were rice fields; 57.3% of them had two or more rice fields plots and 45% had more than two *kebun*

campuran plots. In general, this condition was to some extent similar to that in the Upper Citarum Watershed, where *kebun campuran* (locally known as *kebon tatangkalan*) owners were considered as local landlords (Parikesit et al. 2005).

In terms of livestock ownership, almost 80% of *kebun campuran* owners possessed livestock like cows, sheep and chickens; almost 41% of them had cows, and 12.6% had sheep. The ownership of these two kinds of ruminants required resources from *kebun campuran* like forages and timber to build animal pens. These two bioresources could be obtained from *kebun campuran* easily and without cost; all respondents acknowledged that the forages needed for their livestock were entirely obtained from *kebun campuran*.

The socio-economic conditions of *kebun campuran* owners in the coastal area of Pangandaran were almost similar to those of the owners of *kebon tatangkalan* (a local term for *kebun campuran*) in the river bank of Citarum (Parikesit et al. 2005). The ownership of *kebon tatangkalan* may reflect socio-economic level of the owners. In the upper Citarum, 96% of *kebon tatangkalan* owners possessed rice fields and/ or vegetable garden, other than *kebon tatangkalan*. Some owners possessed one to three hectares of agricultural land, yet, not less than 40% of villagers in the study sites were landless; the average land ownership in the present study area is not more than 0.2 ha. Despite the elevating price of agricultural land due to its limited availability, it was common for owners to purchase the land; 75.3% of acquiring owners acquired *kebon tatangkalan* land by purchasing from other villagers.

Generally, it can be said that *kebun campuran* owners enjoyed more abundant resources compared to other residents. Various needs to support their livelihood were sourced from *kebun campuran*. This shows that owning *kebun campuran* helped them to have autonomy in fulfilling their life needs. In terms of food security, the owners of *kebun campuran* had more secure resources because the yield from *kebun campuran* could increase their ability to purchase food to meet their daily needs. Amid intensive environmental changes due to regional development, the present study showed that the role of agroforestry, in general, is still relevant to guarantee the fulfillment of local people. Therefore, it is not exaggerating to state that maintaining agroforestry systems like *kebun campuran* is an important measure to obtain multidimensional benefits as pointed out in the Sustainable Development Goals (Anderson 2018).

The results of the Pearson correlation analysis show that the larger the yard and the rice fields owned by the respondents, the larger the area of owned *kebun campuran* (Table 3). The results of this correlation analysis clinch the opinion that *kebun campuran* owners were local landlords controlling the land in the village for generations. The control of the land was not limited to the villages where they lived, but also in neighboring ones. However, there was no correlation between the area of the yard and the rice fields owned by the respondents. This suggests that owners who possess large *kebun campuran* did not always mean to have large rice fields as well. It was very uncommon for village residents to build their homes and yards in the rice fields. Villager who built a house in the rice fields, usually did not have *kebun campuran* plot. On the other hand, building houses and yards on *kebun campuran* lands was a common practice at the study sites and it was found that on a large *kebun campuran*, the owner could build a house with a large yard.

The process/ mechanism of kebun campuran ownership

Most owners (85.5%) stated that they obtained *kebun campuran* from inheritance, while another common way of obtaining was through purchasing it. (Table 4). This reinforces the fact that *kebun campuran* was heritage family asset inherited from generation to generation. In addition to inheritance and purchase, renting *kebun campuran* was done by several owners, but this was not a common practice at the study sites.

Table 2. Socio-economic profile of *kebun campuran* owners in the karst ecosystem

Description	**Percentage (n = 89)**
Origin of the owner	
Native residents	84.3
Migrants	15.7
Education	
Does not go to school	5.6
Elementary school	59.6
Junior high school	15.7
High school	13.5
University	5.6
House type	
Permanent	80.9
Semi-permanent	14.6
Non-permanent	4.5
Asset ownership	
Yard	
<200 m ^{2}	46
200-<400 m ^{2}	18
400-<600 m ^{2}	18
600-<800 m ^{2}	6.7
800-<1000 m ^{2}	7.9
1000 + m ^{2}	3.4
Number of plots of land owned	
None	6.7
1 plot	36
2-3 plots	34.8
> 3 tiles	22.5
Number of *kebun campuran* plot	
Only 1 plot	55
2-3 plots	20.3
> 3 tiles	24.7
Livestock ownership	
Yes	79.8
Not	20.2
Types of livestock owned (n = 71)	
Cow only	19.7
Chicken only	47.9
Sheep only	4.2
Cow and chicken	18.3
Chicken and sheep	5.6
Cow, chicken, and sheep	2.8
Others	1.4

Table 3. Pearson correlations of the ownership of yard, *kebun campuran*, and rice field area

	Yard	Rice fields	*Kebun campuran*
Yard	-	0.153	0.269 *
Rice fields	0.153	-	0.609 **
Kebun campuran	0.269 *	0.609 **	-

Note: *= 0.1 and **= 0.05 level of significance

Table 4. Ways and years of obtaining *kebun campuran* and purchase transactions of *kebun campuran* among residents (inside/outside the village)

Description	Percentage (n = 89)
Way of obtaining *kebun campuran*	
Inheritance	33.7
Purchasing	14.6
Inheritance and purchasing	48.3
Inheritance and rent	3.4
Year of obtaining *kebun campuran*	
Before the 1970s	15.7
1970-before 1990	23.6
1990-before 2010	39.3
2010 and after	20.2
Do not know/forget	1.1
Purchase transactions of *kebun campuran* (n = 26)	
Among local residents	96.1
Among residents of other villages	3.9

Kebun campuran system at the present study sites appeared to have been a part of the coastal rural landscape and was practiced for a long time by the local community. This was indicated by the statement of 15.7% of respondents saying that most of them had had *kebun campuran* since before the 1970s obtained through inheritance. That meant that their parents had owned this agroforest for at least 50 years ago.

In case of buying and selling of *kebun campuran*, transactions between residents of different villages rarely happened. This study revealed that almost all respondents (96.1%) who owned *kebun campuran* by purchasing obtained it from residents of the same village. For *kebun campuran* owners, it seemed that the sale and purchase of *kebun campuran* plots could increase in the economic value, given the increasing land prices over time.

The main functions of kebun campuran

Kebun campuran had various functions for the owners (Table 5). Almost all respondents (93.2%) stated that *kebun campuran* was an economic source of their household. More than 50% of *kebun campuran* owners claimed that the various products from *kebun campuran* was a source of family income which contributed to more than 50% of the total income.

Almost all owner respondents (91.1%) earned their income from selling the products derived from *kebun campuran* as wholesale. This way of selling was considered more practical as it involved receiving large amount of money upfront.

Table 5. The main functions of *kebun campuran* for their owners

Description	Percentage (n = 89)
Functions for the owners	
Family economic resources	93.2
Assets to be passed on later	88.8
Reserved land for building a house	13.5
Family assets that can be sold at any time	9.0
Contributions of *kebun campuran* to owners' household income	
<3 0%	20.2
3 0-< 50%	24.7
More than 50%	55.1
Ways to sell wood harvested from *kebun campuran*	
Wholesale trade	91.1
Unit trade	5.6
Sold to buyers	1.1
Never sold it	2.2
Timber source for building or renovating *kebun campuran* owners' house	
Kebun campuran	75.3
Building material stores	19.1
Scraps of building materials	1.1
Others	4.5
Source of forage (n = 71)	
Rice mill	5.6
Rice fields only	40.8
Kebun campuran only	32.4
Rice fields and *kebun campuran*	16.9
Purchase	4.2
Source of building materials for livestock pens (n=71)	
Yard	1.4
Purchase from building material store	14.1
Kebun campuran	63.4
Scraps of building materials	16.9
Sawmill	1.4
Purchase a ready-made shed	1.4
Livestock not put in a shed	1.4

For its owners, *kebun campuran* had several main functions like in supplying timber to build or renovate their houses. The majority of owners (75.3%) relied on *kebun campuran* as a source of timber, while for others who also owned livestock, *kebun campuran* was a source of forage for their livestock and a source of timber to build livestock pens, especially for ruminants such as sheep and cows.

Based on the most frequently sold and most profitable plant species, 93.3% of respondents stated that coconut (*Cocos nucifera*) was the most frequently sold commodity; 78.7% stated that this palm plant was the most profitable (Table 6). Other than coconuts, various types of fruit plants and wood that were the most suitable with the local agro-climatic conditions were introduced to *kebun campuran* several decades ago. *Kebun campuran* is a type of land use where plant biodiversification takes place through various stages of introduction, domestication, selection, and expansion.

Table 6. Some plant species of *kebun campuran* that were the most often sold and profitable

Vernacular names	Scientific names	% of respondents	
		Most often sold	Most profitable
Coconut	*Cocos nucifera*	93.3	78.7
Albasiah	*Albizia chinensis*	3.3	15.7
Banana	*Musa paradisiaca*	1.1	2.2
Sawo	*Manilkara zapota*	1.1	0
Mangosteen	*Garcinia mangostana*	0	2.2

Table 7. Energy sources for domestic needs

Description	Percentage (%)
Energy type (n = 89)	
LPG only	16.9
Firewood only	23.6
LPG and firewood	59.5
Firewood dominant	56.6
LPG dominant	35.8
Balanced between firewood and LPG	7.6
Main source of firewood (n = 74)	
Kebun campuran	64.9
Scraps from buildings	5.4
Scraps from sawmills	4.1
Others (e.g. fields, yards)	25.7
Use of firewood from *kebun campuran* (n = 48)*	
Own consumption	94.6
Give to neighbors	9.5
Sell to other people	14.9

Note: * the total percentage exceeds 100% because among those who use firewood for own consumption also sell the firewood

One of the most recent species to experience this process in the present study sites was *albasiah* (*Albizia chinensis*) which was one of the species that had important economic value widely cultivated by *kebun campuran* owners. Despite only 3.3% of the owners admitted that this timber species was the most sold, 15.7% claimed that this species was the most profitable, and for this reason they planted it in their *kebun campuran*. Interestingly, mahogany known as one of the world's one of finest-quality woods but in the present study sites, it was not commonly planted. None of the respondents stated that this wood was often sold and was profitable. It may be due to the species being slow-growing and requires about 25 years to reach its maturity and takes around 122 years on an average to reach the 55-cm minimum cutting diameter (Snook 2003).

Kebun campuran as domestic energy source

As seen in Table 7, only 23.6% of respondents used firewood as a single source of household energy. Overall, single and combined fuelwood users were 83.2%, and among the combined firewood users, the majority (56.6%) relied more on firewood for their daily needs. Ownership of *kebun campuran* helped the people in meeting the needs of firewood for free. It was not surprising, therefore, that the majority of owners (64.9%) who used firewood made their *kebun campuran* as the only source of wood. Those who used firewood as a single source of household energy collected this biomass energy at least once a week to meet their daily needs, while those who combined the use of firewood and LPG did not have a fixed schedule in collecting it. The present study shows clearly that *kebun campuran* is very important to replace natural forest in supplying free domestic energy. As the present study is located not far from the conservation forest, maintaining *kebun campuran* as source of firewood is very important to reduce pressure on natural forests.

According to most of the respondents (94.6%), firewood from their *kebun campuran* was predominantly used for self-consumption, and only a small proportion was sold and or given to their neighbours. Although only on a small scale, *kebun campuran* was one of the important sources for poor people in meeting cheap (free) biomass energy. A study conducted in the upper Citarum watershed indicated that firewood originated from *kebon tatangkalan* had a social value for the owner (Parikesit 2001), i.e., to give away free firewood to others. Furthermore, for rural residents who live far away from the forest, *kebon tatangkalan* is the only source of firewood that can be obtained for free.

The management of kebun campuran

From Table 8 it can be seen that the overall management of *kebun campuran* was not carried out as intensively as the management of rice fields. Only a small percentage of *kebun campuran* owners (25.9%) regularly fertilized their plots. Likewise, the majority of owners never conducted pest and disease control, which was different from weeding activities where most of the owners (66.3%) often did. These activities were carried out to maintain plants with good economic values so that they could grow well and have high production.

Pruning activities were mainly carried out by *kebun campuran* owners who used firewood as their main domestic energy. At the same time, this activity was performed to maintain the productivity of the plants. Lastly, the most important activity according to almost all respondents (91%) was to rejuvenate plants with high economic value species. This was to ensure the productivity of *kebun campuran* remained high in the long run. Okubo et al. (2010) pointed out that in agroforestry systems like *talun* (*kebun campuran*), a trade-off between biodiversity conservation and income could be performed. The trade-off is important in maintaining biodiversity condition and people's income in a landscape where human intervention was intensive. In relation to this, *kebun campuran* seems to be the appropriate system to implement the concept of 'biodiversity by design' as a conservation strategy (Mohamad et al. 2013).

The dynamics and the future of kebun campuran.

Indications that *kebun campuran* had long existed in the study area were indicated by response that they owned *kebun campuran* for generations (Table 9). Persons

(43.8%) who owned *kebun campuran* by purchasing it did not know about the origin of land. However, it was known that almost all of the *kebun campuran* areas were once dominated by coconut plants.

As many as 70.8% of *kebun campuran* owners admitted that they had at least once changed their land use from other usages to houses. Among those who made these changes, 41.3% of them changed from *kebun campuran*, while most of the others (54%) changed from rice fields or yards. On the question of changing land use from *kebun campuran* or others to houses, it was known that 41.3% of respondents did so after the 2000s, whereas changes made in the previous periods were only carried out by 12% of respondents (before the 1980s), and 31.7% between the 1980s and as early as the 2000s. Changes in land use after the 2000s occurred partly due to the increasing need for land for settlements. This was in line with the natural population growth and migration from outside the region.

Regarding the existence of *kebun campuran* in the future, the majority of owners (61.8%) including local resident and migrant owners stated that they would maintain their *kebun campuran*. However, they had not been able to ascertain whether their *kebun campuran* would be passed on, sold, or used as other alternatives. 33.7% who had inherited *kebun campuran* from their elders had ensured that their *kebun campuran* would be bequeathed for their descendants. While only a small number were not yet able to determine what to do with their *kebun campuran* in the future.

Economic value of various derived products and livelihood support are some of the primary reasons behind maintenance of *kebun campuran* generation after generation. Presence of *kebun campuran* and its sustainability in karst ecosystem of the coastal area of Pangandaran is crucial from both the fragile ecosystem and international tourism destination point of view. To some extent, fresh organic produce from *kebun campuran* and traditional cuisines may add to the platter of visitors. However, tourism needs to be sustainable in a way development of regional supporting infrastructure shall have minimal impact upon local ecosystem and understanding the future prospects local rural communities should plan conservation of the unique *kebun campuran* in karst ecosystem, and develop community-based rural tourism in future.

Table 8. Activities carried out in the management of *kebun campuran*

Activities	Intensity (%)		
	Never	Rarely	Often
Fertilization	44.9	29.2	25.9
Pest and disease control	74.1	18.0	7.9
Weeding	2.2	31.5	66.3
Pruning	41.6	29.2	29.2
Making terrace	78.7	10.1	11.2
Plant replanting	9.0	68.5	22.5

Table 9. Future dynamics and existence of *kebun campuran*

Description	Percentage (%)
The origin of *kebun campuran*	
Rice fields	4.5
Kebun campuran	51.7
Do not know	43.8
Land ownership switch	
No	29.2
Yes	70.8
Change from plots other than *kebun campuran*	54.0
Change from *kebun campuran*	41.3
Change from a vacant lot	4.7
Turn into a house	
Yes	100
Not	0
Year of changing land functions (n = 63)	
Before the 1980s	27.0
1980-before 1990	12.7
1990-before 2000	19.0
After 2000	41.3
The existence of *kebun campuran* in the future	
Maintained and not yet determine to sale or pass on to other	61.8
Pass on	33.7
Do not know	4 .5

Bio-ecological dimensions of kebun campuran

Composition of types of plants in kebun campuran

Species inventory carried out in *kebun campuran* in the study sites led to the identification of 76 species of trees and other perennials, out of which only 28 species were used as building materials, firewood, and fruit(Table 10). Overall, the diversity of fruit trees was the highest (18 bioresources), followed by species used for building materials (11 bioresources), and for firewood (7 bioresources). There were also various other tree species that had good economic potentials but they were uncommonly planted by *kebun campuran* owners, including *Artocarpus integer* (breadfruit), *Syzygium aqueum* (water apple), *Psidium guajava* (guava), Semecarpus *anacardium* (jambu bol), *Pithecellobium jiringa* (jengkol) and *Dimocarpus longan* (longan).

Albizia chinensis (albasiah) was the most important species for building material and firewood, while *Cocos nucifera* (coconut) was a species that had three kinds of uses, and also for making brown sugar. The fruit trees considered the most useful because of their high economic value were *Manilkara zapota* (sapodilla) and *Garcinia mangostana* (mangosteen).

Horizontal structure of kebun campuran vegetation

The results of the vegetation analysis which also was consistent with the results of the interviews carried out with *kebun campuran* owners showed that the structure of *kebun campuran* vegetation was dominated by fruit plants and wood plants used for building materials (Figure 2; Table 10).

These results also reinforced the statement of *kebun campuran* owners about the economic functions of *kebun campuran*, and this was clearly seen from the dominant species having high economic value such as albasiah, coconut, caruy, sapodilla, duren, and duku. The dominant plant species tend to be similar in all three categories, and this fact reinforced the statement from *kebun campuran* owners that the replanting of plant species was an important activity. Albasiah, coconut, and caruy were some species routinely replanted because of their higher economic value compared to other species. Species such as sapodilla, duren, and duku had been introduced in the study site since the last few decades, although they were not as dominant as albasiah and coconut. It seems that the introduction and cultivation of more diverse species was constrained by the biophysical conditions in the karst ecosystem. As a result, the diversity of plants, especially those with important economic values was quite low as indicated by the Shannon-Wiener Diversity Index that was moderate or below moderate in the sapling group (1.76), pole (2.05), and mature tree (1.78).

Species richness, diversity index, correlation between kebun campuran area and the number of species and the number of individuals.

The present study suggested-that the diversity based on the number of plant species was quite high (76 species), although the Shannon-Wiener Diversity index (H') was only 1.78. This means that despite *kebun campuran* had a fairly high species richness, the presence of several dominant species (indicated by high Summed Dominance Ratio values) such as coconut, albasiah, and sapodilla resulted in low H'index.

The results of the Pearson correlation showed (Table 11), that the diversity of species and the density of tree individuals were positively correlated with the area of *kebun campuran.* The results showed that the owners strategically optimized the area of *kebun campuran* by biodiversification and increased the abundance of species that had important economic values, which led to maximized economic benefits for the owners. This was consistent with the management activities carried out by almost all *kebun campuran* owners in terms of plant replanting (Table 6).

Table 10. Various plant species commonly found in *kebun campuran*, their main uses (√), and ranks of importance (number)

Vernacular name	Scientific name	Usability (rank)		
		House building /shed	Firewood	Fruit for consumption
Albasiah	*Albizia chinensis*	√ (1)	√ (1)	
Alpuket	*Persea americana*			√
Belimbing	*Averrhoa carambola*			√
Bungur	*Lagerstroemia speciosa*	√		
Caruy	*Macropanax dispermus*	√ (3)	√ (3)	
Duku	*Lansium parasiticum* var. *duku*			√
Duren	*Durio zibethinus*	√		√
Heras	*Vitex pinnata*		√	
Jati	*Tectona grandis*	√	√	
Jati bodas	*Gmelina arborea*	√		
Jeruk	*Citrus nobilis*			√
Kedondong	*Spondias mombin*			√ (5)
Ki taleus	*Phoebe sheareri*	√ (4)	√	
Kelapa	*Cocos nucifera*	√ (2)	√ (2)	√ (1)
Limus	*Mangifera foetida*			√
Mahoni	*Swietenia macrophylla*	√ (5)	√ (4)	
Mangga	*Mangifera indica*			√
Manggis	*Garcinia mangostana*			√ (3)
Nangka	*Artocarpus heterophyllus*			√
Pisang	*Musa paradisiaca*			√ (4)
Kokosan	*Lansium parasiticum* var. *aquaeum*			√
Rambutan	*Nephelium lappaceum*			√
Salak	*Salaca zalacca*			√
Salam	*Syzygium polyanthum*	√		
Sawo	*Manilkara zapota*			√ (2)
Sirsak	*Annona muricata*			√
Pisitan	*Lansium parasiticum* var. *domesticum*			√
Wangkal	*Albizia procera*	√		

Table 11. Pearson's correlation between *kebun campuran* area, number of plant species, and number of plant individuals

	Area of *kebun campuran*	Number of species	Number of individuals
Area of *kebun campuran*	-	0.485 **	0.691 **
Number of species	0.485 **	-	0.594 **
Number of individuals	0.691 **	0.594 **	-

Note: **= 0.05 level of significance

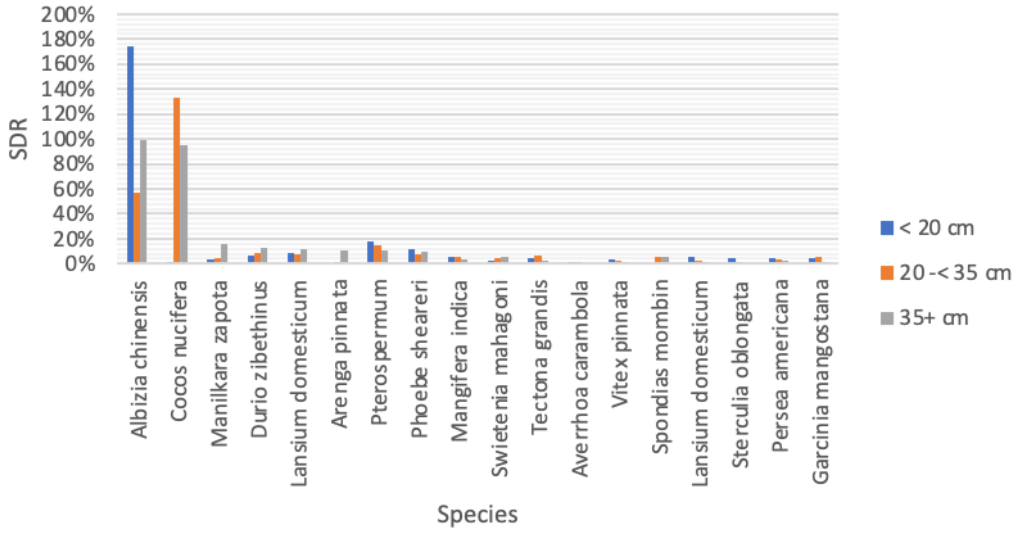

Figure 2. Summed Dominance Ratio (SDR) value (%) of several tree species in three classes of stem diameter (diameter 1: <20 cm; diameter 2: 20-<35 cm; diameter 3:> 35 cm)

The composition of plant species in *kebun campuran*, including both horizontal and vertical structures of vegetation that resembled miniature forests would attract various types of animals to use them as part of their habitat. In *kebun campuran*, various bird species were found; one of them being *Psilopogon javensis* (locally '*takur tulung* tumpuk') which had the conservation status of 'near threatened' according to the International Union for Conservation of Nature (Muladi et al. 2018). This indicates that *kebun campuran* had an important role in biodiversity conservation in human-dominated landscapes. Previous study conducted in the upper Citarum watershed concluded that bird diversity in agroforestry vegetation was influenced more by the complexity of canopy cover and the heterogeneity of landscape than by the diversity of plant species (Parikesit et al. 2012). Similar observation was also recorded in *kebun campuran* in the karst ecosystem of the Pangandaran. bird diversity based on the Shannon-Wiener diversity index was 2.85 and the Evenness Index was 0.96. The two indices suggested a high diversity of bird species that inhabited *kebun campuran* and that none of the bird species dominated *kebun campuran* habitats.

Apart from its role as habitat for various bird species, *kebun campuran* in the karst ecosystem was also a habitat for various mammals (Withaningsih et al. 2017). Two species of protected mammals using *kebun campuran* as their habitat, viz. *Manis javanica* (Sunda pangolin) and *Nycticebus javanicus* (Javan Slow Loris). The discovery of various mammals and birds on the coast of Pangandaran, especially those that were protected, showed how the economics and ecological functions could be compromised. On a wider landscape context, as a man-made ecosystem *kebun campuran* became complementary element to a more natural ecosystem like the one in the Pananjung Pangandaran Nature Reserve (CAPP) which was not too far from the study sites.

In conclusion, the present study concludes that *kebun campuran* in the karst ecosystem of coastal Pangandaran had important economic, social, and ecological functions. As the *kebun campuran* patch became larger, its economic value derived from its products became higher. Apart from that, the larger the patch area the higher the plant diversity and density suggesting that *kebun campuran* had also important role in biodiversity maintenance in the karst ecosystem. The mimicking forest exhibited by *kebun campuran* has made this multi-layered agroforestry an important habitat for wildlife. Maintaining the future of *kebun campuran* will lead to the conservation of karst ecosystem amid rapid development of infrastructures to support increased tourism and its related economic activities in coastal Pangandaran. With regard to this, relevant regulation aimed to protect the multidimensional functions of *kebun campuran* should be considered.

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REFERENCES

Anderson L (ed.). 2018. Achieving the Global Goals through Agroforestry. Agroforestry Network and VI-Skogen. Stockholm.

Cooper PJM, Leakey RRB, Rao MR, Reynolds L. 1996. Agroforestry and the Mitigation of Land Degradation in the Humid and Sub-humid

Tropics of Africa. Exp Agric 32: 235-290. DOI: 10.1017/S0014479700026223.
Christanty L, Mailly D, Kimmins JP. 1996. Without bamboo, the land dies: Biomass, litterfall, and soil organic matter dynamics of a Javanese bamboo talun-kebun system. For Ecol Manag 87: 75-88. DOI: 10.1016/S0378-1127(96)03834-0.
Sood KK, Mitchell CP. 2009. Identifying important biophysical and social determinants of on-farm tree growing in subsistence-based traditional agroforestry systems. Agroforest Syst 75: 175-187. DOI: 10.1007/s10457-008-9180-z.
Leimona B, van Noordwijk M. 2017. Smallholder agroforestry for sustainable development goals: ecosystem services and food security. Palawija Forum 34: 1-6.
Lynch SJF, Hollnsteiner M, Covar L. 1974. Data Gathering by Social Survey. Philippine Social Science Council Social Survey Series No. 2, Quezon City, Philippines.
Mailly D, Christanty L, Kimmins JP. 1997. 'Without bamboo, the land dies': nutrient cycling and biogeochemistry of a Javanese bamboo *talun-kebun* system. For Ecol Manag 91: 157-173. DOI: 10.1016/S0378-1127(96)03893-5.
Martini E, Hesti LT, Elok M, Jusupta T. 2010. Building Mixed Farm: Learning form Kobun Pocal in Tapanuli and Lampoeh in Tripa. World Agroforestry Centre, Bogor.
Mohamad NHN, Idilfitri S, Thani SKSO. 2013. Biodiversity by Design: The attributes of ornamental plants in urban forest parks. Procedia Soc Behav Sci 105: 823-839. DOI: 10.1016/j.sbspro.2013.11.085
Montagnini F, Metzel R. 2017. The Contribution of Agroforestry to Sustainable Development Goal 2: End Hunger, Achieve Food Security and Improved Nutrition, and Promote Sustainable Agriculture. In: Montagnini F (ed.). Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Adv Agroforest 12. Springer, Cham. DOI: 10.1007/978-3-319-69371-2_2.
Muladi F, Withaningsih S, Iskandar J, Parikesit. 2018. Keanekaragaman Jenis Burung Reeps (Rare, Endangered, Endemic, Protected Species) di calon kawasan geopark pangandaran, Jawa Barat. Biotika J Ilmiah Biol 16: 70-76. [Indonesian]
Mwase W, Sefasi A, Njoloma N, Nyoka B, Manduwa D, Nyaika J. 2015. Factors affecting adoption of agroforestry and evergreen agriculture in Southern Africa. Environ Nat Res Res 5: 148-157. DOI: 10.5539/enrr.v5n2p148.
Okubo S, Parikesit, Harashina K, Muhamad D, Abdoellah OS, Takeuchi K. 2010. Traditional perennial crop-based agroforestry in West Java: the trade off between on-farm biodiversity and income. Agrofor Syst 80. 17-31. DOI: 10.1007/s10457-010-9341-8.
Ong CK, Black CR, Muthuri CW. 2006. Modifying forestry and agroforestry to increase water productivity in the semi-arid tropics. Perspect Agric Vet Sci Nutr Nat Resour 1: 65. DOI: 10.1079/PAVSNNR20061065.
Parikesit, Takeuchi K, Tsunekawa A, Abdoellah OS. 2001. Non-forest fuelwood acquisition and transition in type of energy for domestic uses in the changing agricultural landscape of the Upper Citarum Watershed, Indonesia. Agric Ecosyst Environ 84: 245-258. DOI: 10.1016/S0167-8809(00)00243-7.
Parikesit, Takeuchi K, Tsunekawa A, Abdoellah OS. 2005. *Kebon tatangkalan:* a disappearing agroforest in the Upper Citarum Watershed, West Java, Indonesia. Agrofor Syst 63: 171-182. DOI: 10.1007/s10457-004-1182-x.
Parikesit, Okubo S, Husodo T, Takeuchi K, Muhamad D. 2012. Biodiversity issues in Indonesia, with special reference to biodiversity in human-dominated landscapes. In: Nakano S, Yahara T, Nakashizuka T. (eds) The Biodiversity Observation Network in the Asia-Pacific Region. Ecological Research Monographs. Springer, Tokyo. DOI: 10.1007/978-4-431-54032-8_8 .
Snook LK. 2003. Regeneration, growth, and sustainability of mahogany in México's Yucatán Forests. In: Lugo AE, Figueroa Colón JC, Alayón M. (eds) Big-Leaf Mahogany. Ecol Stud (Anal Synth) 159. Springer, New York. DOI: 10.1007/0-387-21778-9_9 .
Tschora H, Cherubini F. 2020. Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. Glob Ecol Conserv 22: e00919. DOI: 10.1016/j.gecco.2020.e00919.
Widiarti A, Prajadinata S. 2008. Characteristics of small scale private forest using mix farming pattern. J Penelitian Hutan dan Konservasi Alam 5: 145-156. DOI: 10.20886/jphka.2008.5.2.145-156.
Withaningsih S, Parikesit, Mustikasari IA, Noorahya F, Akbar MN. 2017. Conceptual planning towards Global Geopark Pangandaran: contribution of biodiversity aspects. Biotika J Llmiah Biol 15: 14-20. [Indonesian]
Yuwariah Y. 2016. The potential of agroforestry to increase income, national independence and environmental improvement. Proc Nat Seminar Agroforestry. Universitas Padjadjaran, Bandung, 19 November 2015. [Indonesian]