Complex agroforestry system in Wan Abdul Rachman Grand Forest Park: composition and characteristics of food-producing plants

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Abstract. Community access to the land of Wan Abdul Rachman Grand Forest Park has started since a long time ago. Since 1998, the community has been permitted to use the land by emphasizing the sustainability aspect. Complex agroforestry systems have been established by combining several tree crops; most of them are food-producing plants. This research was aimed to study the composition and characteristics of the food-producing plant species, canopy strata, and its regeneration rate in the context of an agroforestry system. The research was conducted at two villages; those were Bogorejo and Cilimus, located in Pesawaran District, Lampung Province, from March to November 2018. Data collection was done through field observation and structured interviews with 59 farmers as respondents who managed the grand forest parkland. Data analysis was conducted using quantitative descriptive analysis method. The results showed that the complex agroforestry practices characterized by three canopy layers and one understory. The mature food-producing plant species proportion was 86.85% of the total food-producing plants with plants density 735.97 individuals/ha. The density of tree crops population 847.42 individuals/ha with the highest density was found for coffee, cacao and candlenut. The existence of immature food-producing plants species was only 13.15%, indicating that the regeneration process had been initiated and conservation effort of the grand forest park still on-going.

1. Introduction
Wan Abdul Rachman (WAR) Grand Forest Park is a Conservation Forest Management Unit located in Lampung Province. Initially, this area was designated as a Protection Forest based on the letter of the Forestry Minister No.742/Kpts-II/1992 dated July 21, 1992, with an area of 22,249.31 ha, which updated later with a letter of the Forestry Minister No. 408/Kpts-II/1993 on August 10, 1993, which stated that the Register 19 area of Mount Betung changed its function from Protected Forest to Conservation Forest Area. As a conservation forest, WAR Grand Forest Park has a function as natural conservation areas for natural and artificial collections of plants and animals, native or non-native species. Those collections are used for the benefit of research, science, and education to support cultivation, culture, tourism and recreation [1]. The grand forest park also has a function as an area of life support systems, especially in regulating water systems, maintaining soil fertility, preventing erosion, maintaining a balance of microclimates, and preserving biodiversity. The land cover area in
WAR Grand Forest Park was 8,200 ha (37%) as primary forest, 4,200 ha (18.78%) as secondary forest, 4,000 ha (18%) as shrubs and *imperata* grasses, and 5,200 ha (23.5%) as gardens and crops [2].

The period of 1994-2014 was a fluctuation in changes WAR Grand Forest Park cover area [3]. The land cover fluctuation occurred on forest cover and agroforestry. From 1994 to 2000 the forest cover area was decreased, one of which due to agroforestry activities. However, in 2000-2014 the area coverage has increased after the growth of various species of tree crops from the application of agroforestry patterns. Changes in forest cover from timber plants to agroforestry tree-crops were the result of community involvement in forest land management.

Giving access to farmers around the forest area is often faced with two possibilities, as a concern to declining forest function that causing reduced canopy cover, so that canopy stratification decreases. On the other hand, entrusting forest sustainability by giving direction to the community will support the efforts to increase land cover in forest areas. The purpose is to maintain existing forest trees and enrich with other species, such as multi-purpose tree species (MPTS) that have benefits both for the environment and economically. Agroforestry pattern with MPTS, especially food-producing perennial tree-crops, is a prospective solution so that the community around the forest can utilize the forest land while maintaining the plant function as land cover.

Agroforestry is a unique land-use system, which combines several tree species either with or without annual food crops or livestock on the same land to obtain various kinds of benefits [4]. Agroforestry has carved out a distinct niche as a robust land-management discipline, and it is now recognized as being at the heart of the global community's commitment to banish hunger and poverty and rebuild resilient rural environments [5]. The future of land use across the world faces many challenges, namely food security, land degradation, desperate poverty, climate change, and others [6]. However, there are many tools to address agroforestry in an integrated and practical way. Agroforestry uses a comprehensive approach, combining traditional knowledge of farmers centuries ago with modern science.

Land no longer just land in the future, but also about the atmosphere, biodiversity, food, water and energy [7]. Agroforestry plays a role in maximizing the use of vertical space (stratification). In other words, it can optimize the absorption of sunlight, which is useful for photosynthesis. Initially, the agroforestry program was aimed at minimizing disturbances in security against the forest. These objectives then developed towards welfare and improving environmental quality [8]. [9] stated that for the tropics, the mandate of agroforestry is described as follows: 1) to increase annual and seasonal food supplies and to improve nutritional quality; 2) to increase product diversification and to reduce risk of crop failure and 3) to guarantee sustainable food supplies [10].

The selection of plant species in agroforestry patterns is unlimited to annual crop species, but preferably various perennial tree-crop species such as fruit trees and other MPTS. A complex agroforestry system needs to be applied urgently to improve and guarantee the sustainability of food production and community livelihoods involved in forest land management. Increasing the food-producing plant components can be done so that food-based sustainable agroforestry will be formed. The application of agroforestry technology (especially in forest areas) is also intended to provide sustainable opportunities or legal access to the community in the use of forest land. In surrounding forest villages, complex agroforestry practices have sustained people's lives for generations because these land-use systems can provide food, shelter, energy, feed and medicine [11 - 14]. The repong damar in Krui and mixed gardens in West Java were proven to provide high biodiversity, play a crucial role in driving the economy - business, and support the socio-cultural stability in the countryside [14].

Communities cultivate the forest land by planting tree-crops according to people's needs and knowledge. The community is free to plant their species of interests so that various tree-crop species planted in the forest areas. In its development, land that has been cultivated for years produces stands like mixed gardens. The characteristics of complex or multi-strata agroforestry systems are the existence of integrated forest trees with crops to form a system that resembles a forest ecosystem [15]. The level of the canopy layer of vegetation can be divided into three to five levels, ranging from layers
of shrubs (vegetables, chili, tubers), treelet (bananas, papaya, ornamental plants) to tall tree layers (up to more than 35 m, for example, resin, durian, duku) [16].

The objective of this research was to determine the composition and characteristics of the species of food-producing plants, plant strata in forming the canopy, and the level of plant regeneration at complex agroforestry systems in the region of WAR Grand Forest Park. The results of this study are useful in providing information about the conditions of vegetation in a location that is managed jointly between WAR Grand Forest Park and the surrounding communities with a complex agroforestry system. The results of this research can be a scientific “justification” for the Regional Technical Implementing Unit (UPTD/Unit Pelaksana Teknis Daerah) of WAR Grand Forest Park to replicate the complex agroforestry system at another place/region.

2. Research Methods
2.1. Time and location of the research
The research was carried out in two villages where the farmers have accesses to utilize and cultivate the land of Wan Abdul Rachman (WAR) Grand Forest Park. Those villages were Bogorejo Village, Gedong Tataan Sub-District and Cilimus Village, Teluk Pandan Sub-district, Pesawaran District. The selection of the research location was carried out purposively, directly adjacent to the WAR Grand Forest Park, and the people get access to the land. The research was carried out from March to November 2018.

2.2. Materials and tools
The main tools and materials used in this study were questionnaires as a guide for interview, recorder and camera to document field data. Other pieces of equipment were calculators and computers to conduct data analysis and research report writing.

2.3. Data collection
The data collected include:

- Primary data from interviews and questionnaires. This primary data include respondents' identities, land tenure, farming characteristics (plant species, number of plants, age of plants, production and condition of plants), and cropping patterns applied in the research location.

- Secondary data obtained from relevant institutions/agencies, for example, the Forestry Office of Lampung Province, Regional Technical Implementing Unit of Wan Abdul Rachman Grand Forest Park, Central Bureau of Statistics and public figures in the villages.

The primary data collection was conducted through interviews and field observation. The number of respondents was 59 farmers, which was chosen randomly according to farmers who worked on the land in the form of agroforestry and incorporated in the Combined Farmers Group (Gapoktan), namely SHK Lestari at Cilimus Village and Gapoktan Karya Makmur at Bogorejo Village. Secondary data were collected through a literature review.

2.4. Data analysis
In this study, the plant composition and characteristics of agroforestry were determined based on interview results about plant species cultivated in the agroforestry plots. Those including the number and area of cultivation, age, and condition of both mature and immature plants.

The data then analyzed qualitatively using descriptive analysis. Descriptive analysis is used to describe or explain a situation from data obtained from interviews and questionnaires.

3. Results and Discussion
Communities who have access to cultivating the forest land of the WAR Grand Forest Park area advised planting tree crops having economic value and forest conservation function. Most of the farmers choose various species of food-producing plants that are classified into multi-purpose tree species (MPTS). The farmers' reason for food-producing plant species were it can be harvested
directly for food purposes or sold to get money. Also, the plants do not need to be cut down in harvesting, and most of them are perennial tree-crops that save new planting costs. Diverse species and age of food-producing plants and irregular cropping patterns have made the forest land cultivation in WAR Grand Forest Park area as mixed gardens.

Mixed gardens or complex agroforestry are seen as having the ability to fulfill the functions of ecological, economic, and socio-cultural of the community [17]. The cultivated species are relatively the same among the farmers. This is following the opinion that the selection of agroforestry component species in tropical regions such as Indonesia and Sri Lanka is based on economic considerations [18, 19].

3.1. Canopy strata, species dominance and plant density of complex agroforestry

The research results showed that there were 22 plant species classified into woody species and seven species classified into understorey plants (filling the lowest canopy strata). All cultivated plants can be grouped into three canopy layers and one understorey. The first stratum consists of four plant species, the second stratum contains 11 plant species, the third stratum has seven plant species and the understorey has seven plant species. Plant species and density in each stratum presented in Table 1.

| No | Plant Species | The respondent who planted the plant | Coverage Planting Area | Plant Density (indv/ha⁻¹) |
|----|---------------|-------------------------------------|------------------------|--------------------------|
|    | Local Name | Scientific Name | Number (person) | Percentage (%) | Area (Ha) | Percentage (%) |                      |
| (a) | (b)         | (c)             | (d)           | (e)          | (f)       | (g)           | (h)                   |
| Strata 1 | | | | | | | |
| 1 | Durian | Durio zibethinus | 55 | 93.22 | 83.87 | 92.04 | 23.99 |
| 2 | Jengkol | Pithecellobium lobatum | 34 | 57.63 | 55.37 | 60.77 | 13.06 |
| 3 | Petai | Parkia spesiosa | 51 | 86.44 | 77.52 | 85.07 | 13.75 |
| 4 | Candlenut | Aleurites moluccana | 49 | 83.05 | 77.87 | 85.46 | 27.43 |

| Strata 2 | | | | | | | |
| 1 | Avocado | Persea americana | 24 | 40.68 | 35.25 | 38.69 | 7.40 |
| 2 | Sugar Palm | Arenga pinnata | 5 | 8.47 | 7.25 | 7.96 | 1.93 |
| 3 | Duku | Lansium domesticum | 5 | 8.47 | 9.5 | 10.43 | 2.95 |
| 4 | Coconut | Cocos nucifera | 14 | 23.73 | 23.12 | 25.37 | 6.01 |
| 5 | Mango | Mangifera indica | 6 | 10.17 | 10.25 | 11.25 | 1.46 |
| 6 | Jackfruit | Artocarpus heterophylla | 11 | 18.64 | 18.25 | 20.03 | 5.10 |
| 7 | Rambutan | Nephelium lappaceum | 2 | 3.9 | 1.75 | 1.92 | 1.14 |
| 8 | Breadfruit | Artocarpus altilis | 4 | 6.78 | 5 | 5.49 | 3.0 |
| 9 | Clove | Eugenia aromatica | 36 | 61.02 | 58.87 | 64.61 | 28.69 |
| 10 | Guava | Psidium guajava | 1 | 1.69 | 1.5 | 1.65 | 1.33 |
| 11 | Nutmeg | Myristica fragrans | 37 | 62.71 | 62.37 | 68.45 | 47.19 |

| Strata 3 | | | | | | | |
| 1 | Melinjo | Gnetum gnemon | 31 | 52.54 | 52.72 | 57.86 | 20.13 |
| 2 | Orange | Citrus sp. | 2 | 3.39 | 2.5 | 2.74 | 8.80 |
Based on Table 1, cacao (Theobroma cacao), durian (Durio zibethinus), petai (Parkia speciosa), candlenut (Aleurites molluccana) and nutmeg (Myristica fragrans) were dominant plant species planted by the respondents. The plant species are considered to have high and stable prices so that many farmers are interested in growing them. Cacao, planted by all respondents, as proof that cacao is a favorite plant species. Cacao is an estate crop favored by most farmers because it has superiority of yield and can be harvested every week [20]. Agroforestry systems provide essential economic and ecological benefits for farmers, one of which can provide income for the farmer family [21]. The application of agroforestry systems provides continuity income, where annual and estate crops are used to meet daily needs [22].

Based on species density, coffee, cacao, nutmeg, moringa and clove were high-density plant species. Coffee and cacao are estate crop species that are widely cultivated and developed in Lampung Province. Both of these species are usually planted in a regular pattern with a spacing of 3 m x 3 m or 3 m x 4 m. However, the number of coffee and cacao plants decreased because of attacked by some diseases that caused a decrease in production and then the farmers replanted with other more profitable commodities. Cacao plants, besides being attacked by rotten diseases, squirrel pests, also cause a decrease in production. Similar to the report in Pasaman District, West Sumatra, cacao owned by farmer was attacked by squirrel pests that had very damaged and often resulted in crop failure [23].

Meanwhile, the nutmeg and clove commodities are expected commodities in the future, and many farmers will be interested in planting them because of the high prices. For nutmeg commodities, almost all parts of fruit can be sold with a high price such as fruit flesh, seeds and fully (epidermis of nutmeg seeds) that are famous as spices. Moringa resides in the third number of density and only planted by one farmer. However, in the future, moringa is predicted to become a leading commodity considering it was recognized as a multi-beneficial plant, especially for health.

In this study, the banana was classified as an understorey plant. While on the other hand, bananas contribute significantly to the base area and canopy closure because the stems are quite large and the canopy is wide [24]. Besides banana, there are six other plant species of food-producing plants as understorey those were chili, Java chili, empon-empon (herbs), taro, pepper and vanilla. Banana, pepper and empon-empon (herbs) are dominant species planted by farmers due to having a reasonable prospect of market.
3.2. Characteristics and composition of mature and immature plants

Based on interviews and questionnaires result, out of 59 agroforestry plots with an area of 91.12 ha, 77,217 plants were found, consisting of 22 species with a density of 847.42 trees per ha. The density of 847.42 trees ha\(^{-1}\) is classified as high and higher than mixed garden density in Pandeglang, which was 613 trees ha\(^{-1}\) [25] and vegetation on Carita Research Forest, which was 502.6 trees ha\(^{-1}\) [24]. Compared to other regions in WAR Grand Forest Park, which are on the tourist track of the Wiyono Atas Waterfall with vegetation density on pole and tree stages as much as 413 trees/ha [26], tree density in the agroforestry area is also higher. The number of food-producing plants species is also more than that of other areas. Although at the Wiyono Atas waterfall tourist track was found 31 plant species, in integrated conservation block of WAR Grand Forest Park, it was found 29 species of trees and understory [27]. However, food-producing plant species were not more than 20 species.

Food-producing plants that were cultivated on the land of WAR Grand Forest Park consisted of various species and ages. The agroforestry system applied in this location can be classified as permanent complex agroforestry or sustainable agroforestry. It is because the component consisted of many species of plants (multiple cropping). It can be characterized by continuously, and irregular cropping pattern either horizontally or vertically with orientation subsistence to semi-commercial land use. Based on interview results, before the community gets access to plant on the land of WAR Grand Forest Park, encroachment and illegal logging occurred frequently. Giving access begins with socialization to provide understanding to the community by the UPTD of WAR Grand Forest Park about planting timber trees and MPTS. Farmers prefer to cultivate MPTS because the species are considered to provide additional income so that benefits can be felt more often than timber plants. This is in line with the Regional Technical Implementing Unit of Wan Abdul Rachman Grand Forest Park's purpose for preserve forest areas sustainably and economically for the community [28].

Food-producing plants can be classified into two groups based on their growth phases. Those were mature plants and immature plants. In general, immature plants are planted in the period from planting time until a moment before they produce yields or plants in the vegetative growth phase, while mature plants are plants that have already produced yield. Characteristics of food-producing plants based on mature and immature plants for each species are presented in Table 2.

| No | Species of Plants | Number of Plants | Mature Plant | Immature Plant |
|----|-------------------|-----------------|--------------|----------------|
|    |                   | Number of Plants| Number (%)   | Plants Density (indv ha\(^{-1}\)) | Number of Plants| Percentage (%) | Plants Density (indv ha\(^{-1}\)) |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
| 1  | Durian | 2,012 | 1,029 | 51.14 | 12.27 | 983 | 48.86 | 11.72 |
| 2  | Jengkol | 723 | 225 | 31.12 | 4.06 | 498 | 68.88 | 8.99 |
| 3  | Petai | 1,066 | 430 | 40.34 | 5.55 | 636 | 59.66 | 8.20 |
| 4  | Candlenut | 2,136 | 1,765 | 82.63 | 22.67 | 371 | 17.37 | 4.76 |
| 5  | Avocado | 261 | 170 | 65.13 | 4.82 | 91 | 34.87 | 2.58 |
| 6  | Sugar Palm | 14 | 10 | 71.43 | 1.38 | 4 | 28.57 | 0.55 |
| 7  | Duku | 28 | 16 | 57.14 | 1.68 | 12 | 42.86 | 1.26 |
| 8  | Coconut | 139 | 117 | 84.17 | 5.06 | 22 | 15.83 | 0.95 |
| 9  | Mango | 15 | 10 | 66.67 | 0.98 | 5 | 33.33 | 0.49 |
| 10 | Jackfruit | 93 | 91 | 97.85 | 4.99 | 2 | 2.15 | 0.11 |
| 11 | Rambutan | 2 | 2 | 100.00 | 1.14 | 0 | 0.00 | 0.00 |
| 12 | Breadfruit | 15 | 15 | 100.00 | 3.00 | 0 | 0.00 | 0.00 |
| 13 | Clove | 1,689 | 523 | 30.97 | 8.88 | 1166 | 69.03 | 19.81 |
Based on Table 2, 86.85% of food-producing plants are mature plants, while 13.15% are immature plants. Immature plants in this study are 1) young plants that have not yet produced; and 2) old plants that do not produce because of various factors, including being attacked by diseases or disrupted growth. Commodities with a higher percentage on mature stage are candlenut, avocado, sugar palm, duku, coconut, mango, jackfruit, rambutan, breadfruit, melinjo, orange, lime, cacao, moringa, coffee and soursop. Meanwhile, commodities with a high percentage on immature stage are jengkol, petai, cloves, guava and nutmeg. The durian percentage of mature and immature plants was slightly the same.

Mature plants have a bigger size than that of immature plants; however, for certain species, there are no immature plants (young plants). It is related to farmers’ decision to select plant species to be cultivated. Rambutan, breadfruit, orange, lime and moringa are mature plants. However, the number of plants, the number of farmers who cultivated the plants, and the plant density are lower when compared to other MPTS such as candlenut, durian, nutmeg and cloves. It is possible because the fruits price is usually fluctuating, the lower absorption of the market, and short of product durability so that the species are less attractive to the farmers. For example, limo, according to respondents in Cilimus, this fruit is reputed as wasted because of limited use (only for sambal and flavor enhancers in satay).

Three high commodities planted by farmers, although they have a low percentage of immature plants, are candlenut, cacao and coffee. Candlenut with high tree habitus (strata 1) has many branches and leaves, so its canopy will shade and disrupt below plant growth. This reason has caused lower farmer interest. Besides, candlenut harvesting is done by collecting fallen fruits on the ground, so many fruits were lost. For cacao species, since the plants were attacked by pests recently, cacao production has decreased. Therefore new plantations of coffee and cacao are not balanced with the number of mature plants. Although these species began to be less desirable, the number of new plants was still quite large, especially coffee and cacao. The cultivation of candlenut, cacao and coffee at the community forest in Sesaot, West Lombok, has several considerations both in terms of economics and ecology [29].

Commodities with a high percentage in immature plants are jengkol, petai, cloves, guava and nutmeg. Jengkol, petai, clove and nutmeg are commodities that much preferred by farmers. The high prices and the broad market absorption make farmers interested in choosing these plant species. Cloves and nutmeg are very promising commodities of spices and many parts of plants can be sold, such as its leaves, flowers (cloves), fruit, seeds and fully (nutmeg). While jengkol, petai and durian are commodities species that are much favored by many people, so prices are relatively stable and high.
Table 3. Species composition and dominance of mature and immature plants.

| No | Plants Species | Number of Plants | Mature Plants | Immature Plants |
|----|----------------|------------------|---------------|-----------------|
| (a) | (b) | (c) | (d) | (e) | (f) | (g) |
| **Strata 1** | | | | | | |
| 1 | *Durian* | 2,012 | 1,029 | 1.333 | 983 | 1.273 |
| 2 | *Jengkol* | 723 | 225 | 0.291 | 498 | 0.645 |
| 3 | *Petai* | 1,066 | 430 | 0.557 | 636 | 0.824 |
| 4 | *Candlenut* | 2,136 | 1,765 | 2.286 | 371 | 0.480 |
| **Strata 2** | | | | | | |
| 5 | *Avocado* | 261 | 170 | 0.220 | 91 | 0.118 |
| 6 | *Sugar Palm* | 14 | 10 | 0.013 | 4 | 0.005 |
| 7 | *Duku* | 28 | 16 | 0.021 | 12 | 0.016 |
| 8 | *Coconut* | 139 | 117 | 0.152 | 22 | 0.028 |
| 9 | *Manggo* | 15 | 10 | 0.013 | 5 | 0.006 |
| 10 | *Jackfruit* | 93 | 91 | 0.118 | 2 | 0.003 |
| 11 | *Rambutan* | 2 | 2 | 0.003 | 0 | 0.000 |
| 12 | *Breadfruit* | 15 | 15 | 0.019 | 0 | 0.000 |
| 13 | *Clove* | 1,689 | 523 | 0.677 | 1,166 | 1.510 |
| 14 | *Guava* | 2 | 0 | 0.000 | 2 | 0.003 |
| 15 | *Nutmeg* | 2,943 | 796 | 1.031 | 2,147 | 2.780 |
| **Strata 3** | | | | | | |
| 16 | *Melinjo* | 1,061 | 1,031 | 1.335 | 30 | 0.039 |
| 17 | *Orange* | 22 | 22 | 0.028 | 0 | 0.000 |
| 18 | *Lime* | 27 | 27 | 0.035 | 0 | 0.000 |
| 19 | *Cacao* | 43,925 | 41,340 | 53.537 | 2,585 | 3.348 |
| 20 | *Moringa* | 25 | 25 | 0.032 | 0 | 0.000 |
| 21 | *Coffee* | 21,000 | 19,400 | 25.124 | 1,600 | 2.072 |
| 22 | *Soursop* | 19 | 18 | 0.023 | 1 | 0.001 |
| **Total** | | | | | | |
| | | 77,217 | 67,062 | 86.849 | 10,155 | 13.151 |

Based on Table 3, in the first layer, dominant species for mature plants were candlenut and durian, while the dominant species for immature plants were *durian* and *petai*. There was a difference between mature and immature plants in terms of dominant plant species. This shows that there is a shift in farmers' interest in plant species to be cultivated, especially candlenut. This was assumed caused by plant canopy factors that are too heavy (tight), selling prices and difficulties in harvesting.

At the second layer, the dominant species for the mature and immature plants were similar, namely nutmeg and cloves. The choice of nutmeg and cloves to be developed is based mainly on economic factors. Both commodities are considered to have relatively high and stable prices. These commodities could be sold directly to consumers as well as for export, so the commodities were considered to become savings for the next few years. According to [30], nutmeg has an excellent prospect to be developed in private forests in Banyumas District because it has economically high and stable prices that provide additional income. Seedling preparation and product marketing are effortless. The government's attention to the development of nutmeg at the production level to post-harvest processing is also quite considerable. Cloves are spices that have the potential to be exported. Indonesian clove production based on production data of the Agricultural Ministry is the largest in the world [31]. Indonesian clove production in 2012 was 99,890 tons, equivalent to 70.99 percent of the
entire clove world's production. Besides that, the quality of Indonesian cloves is also the best in the international market. The quality standards of Indonesian clove production are very high [32].

In the third layer, the dominant mature and immature plants were also similar, namely cacao and coffee. Cacao and coffee are estate crop species that were widely developed by communities in various regions, especially with agroforestry patterns or mixed gardens. Cacao and coffee were planted with regular spacing (3 m x 3 m or 3 m x 4 m), and variations of the plants' age were not so many (both mature and immature plants) because planting was done simultaneously. In its development, many cacao plants were cut down due to pest and disease attack. Then it was replaced by MPTS that is economically and does not need intensive maintenance. However, cacao and coffee are still farmers' choice because Lampung Province is one of the leading cacao and coffee-producing areas. Also, the two commodities are shade-tolerant plant species, so they are suitable to be planted at a lower layer.

**Table 4.** Characteristics and species composition of understorey.

| No | Plant Species | Number of Plants | Mature Plants | Immature Plants |
|----|---------------|------------------|---------------|-----------------|
|    |               | Number of Plants | Percentage of Plants | Plants Density (indv ha⁻¹) | Number of Plants | Percentage of Plants | Plants Density (indv ha⁻¹) |
| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
| 1 | Chilli | 240 | 240 | 100.00 | 14.33 | 0 | 0.00 | 0.00 |
| 2 | Java Chilli | 1,830 | 1,130 | 61.75 | 113.00 | 700 | 38.25 | 70.00 |
| 3 | Empon-empon (herbs) | 506 | 506 | 100.00 | 25.95 | 0 | 0.00 | 0.00 |
| 4 | Pepper | 2,274 | 534 | 23.48 | 24.16 | 1,740 | 76.52 | 78.73 |
| 5 | Banana | 1,524 | 1,144 | 75.07 | 48.99 | 380 | 24.93 | 16.27 |
| 6 | Taro | 606 | 106 | 17.49 | 8.31 | 500 | 82.51 | 39.22 |
| 7 | Vanilla | 1,700 | 300 | 17.65 | 30.00 | 1,400 | 82.35 | 140.00 |

Land under tree stand was used by farmers to plant various annual crops, especially for fulfilling their daily needs and some commodities that can be sold (Table 4). Chilli and taro were two commodities that were planted irregularly and relatively not intensively maintained because the results were only used for self-consumption. While bananas and empon-empon (herbs), although they were not planted intensively, the products were mostly sold to get additional family income. Lampung Province is one of the clusters for banana production in Indonesia, and Pesawaran District in 2017 was the third-largest supplier of banana production in Lampung, after the districts of South Lampung and East Lampung which was 411,923 tons (28.17%) [33].

Pepper, vanilla and Java chili are plant species under tree stand that farmers very interested in planting them since the prices were relatively high and stable. In the periods before and during the economic crisis, the competitiveness of many Indonesian spice commodities was low. In contrast, in the post-economic crisis, the condition of competitiveness of those spices increased, especially vanilla, cinnamon, ginger, turmeric, saffron, thyme, bay leaves, curry leaves, and pepper [34]. While Java chili, the planting was initially concentrated on the island of Java, but now it has been widely planted in Madura, Sulawesi, Lampung and Ambon. In Lampung, transmigrants from Java have developed Java chili on dry land, both monoculture and mixed with pepper plants [35].

In addition to economic considerations for increasing the income, the selection of pepper, vanilla and Java chili crops also aims to utilize the presence of trees on the higher strata, which can be used as
"climbing or trajectory" and shading. The function of life trajectory in pepper cultivation is for climbing poles, regulating humidity and environmental sustainability, as well as the continuity of life of pepper plants throughout their life cycle [36]. The life trajectory is also useful to reduce plant stress, especially during the dry season since the pepper plant only requires 50-75% sunlight intensity [37]. While for vanilla, protective trees are useful for attaching, climbing and shading because vanilla only needs 30-50% radiation intensity [38].

3.3. Regeneration of agroforestry plants

Immature plants consist of two categories, namely young plants and old plants, which do not produce due to various factors. Young plants are the result of new planting. The purpose of farmers replanting is to replace dead trees, enrichment of species, multiplication of species that have economic value and conservation efforts by maintaining strata of land cover and productivity. The dominant plant species of mature and immature plants are presented in Table 5.

| No | Mature Plants | Immature Plants |
|----|---------------|----------------|
|    | Dominant Species | Total of Plants | Percentage (%) | Dominant Species | Total of Plants | Percentage (%) |
| Habitus of Trees |
| 1  | Cacao         | 41,340         | 53.54         | Cacao         | 2,585         | 3.35         |
| 2  | Coffee        | 19,400         | 25.12         | Nutmeg        | 2,147         | 2.78         |
| 3  | Candlenut     | 1,765          | 2.29          | Coffee        | 1,600         | 2.07         |
| 4  | Melinjo       | 1,031          | 1.34          | Clove         | 1,166         | 1.51         |
| 5  | Durian        | 1,029          | 1.33          | Durian        | 983           | 1.27         |
| Understorey |
| 1  | Banana        | 1,144          | 28.89         | Pepper        | 1,740         | 36.86        |
| 2  | Java Chilli   | 1,130          | 28.54         | Vanilla       | 1,400         | 29.66        |
| 3  | Pepper        | 534            | 13.48         | Java Chilli   | 700           | 14.83        |

The dominant species of mature plants and immature plants were different. It related to farmers' choice for cultivating the forest land, which expected to become a source of family income. Farmer's reasons for cultivating specific species in Sungai Langka Village were generally cash income, continuity of production, rate of production, ease of maintenance and harvesting, easy of post-harvest processing, suitable to plant with other crops, and security of land governance [39].

Cacao remains the dominant plant species, although regeneration percentage has decreased compared to other species such as coffee. The population of coffee has decreased both in percentage and in the dominant order of species planted by farmers. The decline in the number of coffee plants has been occurred since a long time ago gradually and some farmers have moved to cacao. Research result in South Sumatra Province revealed factors that influence farmers to change from coffee to cacao plants were including the age factor of coffee plants, farmers' perceptions on cacao (that can provide greater benefits), cultivation methods, comparison of prices of both commodities and ease in post-harvest processing [40]. Similar to coffee, land area and cacao production were also decreased in Lampung Province in 2017. Based on Lampung Province in Figures 2017 and 2018 [41, 33], cacao production declined from 56,272 tons (land area 86,869 ha) in 2016 to 45,046 tons (land area 71,138 ha) in 2017, while coffee production decreased from 128,074 tons (land area of 161,320 ha) to 114,214 tons (land area 158,015 ha). According to the interview results, weather and rot fruit disease of cacao influence the decline in the harvest area and yield of the two commodities.

It was interesting that the farmer's preference has increased in planting nutmeg and clove as tree crops in the second layer. Therefore, the population of spice plants began to increase in recent years.
Spice plants are estate crops. The primary commodities of spices are pepper, clove, nutmeg, vanilla and cinnamon [38]. In addition to cinnamon, the other four commodities also attracted the farmers’ interest to cultivate them. Those spice plants have high economic value. Clove and nutmeg plants have multi-products, so the economic value is higher.

Although *durian* is not the dominant species, it is still a prime commodity to be developed because it has a stable economic value, and demand for this luxury fruit is relatively high at a relatively high price. Also, in the form of high tree habitus, *durian* is suitable for planting in the agroforestry system as its canopy fills the space in the first layer and provides shade.

Banana is one of the commodities that widely developed in Lampung Province. Banana chips production is a market that continuously requires the raw materials of bananas. Besides, these products are also sent outside the area as fresh fruit products. Bananas are widely planted in gardens and home yards to be sold or for their consumption.

Based on data in Table 5, the banana did not appear in the dominant immature plants. This condition causing by banana products were sold to the market to increase income; they were not the main product of the land that farmers expected for their family income. Therefore, when other plant species have better economic prospects, farmers will develop other species. In this case, pepper, vanilla and Java chili species were considered to have a better prospect to be developed. According to Agriculture Ministry data, banana production in Lampung Province was decreased, namely 1,937,348 tons in 2015; 1,517,004 tons in 2016 and 1,462,423 tons in 2017 [42]. Nevertheless, there was a deep study for knowing banana production decline.

Spices plants were being favored, including pepper, vanilla and Java chili. The average age of pepper and vanilla plants were still 2-3 years, so they were still in the immature plants’ stage and have not yet produce yield.

4. Conclusion
The food-producing plants’ species number cultivated at complex agroforestry systems in Wan Abdul Rachman Grand Forest Park areas were 22 woody species and seven species of underground plants. All plants formed three canopy strata. The first stratum consisted of four plant species, the second stratum contained 11 plant species, the third stratum had seven plant species, and the understorey had seven plant species. Coffee, cacao and nutmeg had the highest tree density. The proportion of mature plants was 86.85% with the dominant species of candlenut and *durian* (strata 1), nutmeg and cloves (strata 2), cacao and coffee (strata 3) and banana and Java chili as understorey. The proportion of immature plants was 13.15% with the dominant species of *durian* and *petai* (strata 1), nutmeg and clove (strata 2), cacao and coffee (strata 3) and pepper and vanilla as understorey. The existence of immature plants, although with a low proportion, indicated that the regeneration process and conservation effort of the Wan Abdul Rachman Grand Forest Park are keep on-going.

Regeneration of woody tree-crops producing food was dominated by cacao, nutmeg, coffee, cloves and *durian*, and for understorey was dominated by pepper, vanilla and Java chili. The difference in dominant species of immature plants compared to mature plants indicated a change or shift in the farmers’ interest in selecting the plants’ species to be planted. The application of complex agroforestry with food-producing plants in the Wan Abdul Rachman Grand Forest Park produced diverse raw material food that could support food security, and at the same time, it conserved forest land cover in the area. The complex agroforestry system could be replicated in other sites of the Grand Forest Park that directly adjacent to the community settlement.

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