Oil palm agroforestry: an alternative to enhance farmers’ livelihood resilience

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Abstract. Oil palm has been rapidly expanding in Indonesia and becoming an important export commodity for the country. However, oil palm production has been promoted only as a monoculture, and this has led to adverse impacts on natural and social systems. At the same time, the demand for oil palm products is likely to increase, and therefore there is an urgency to find alternatives for more sustainable oil palm production. We argue that the monoculture system is not necessarily to be the only way to produce oil palm and this article aims at analysing alternatives for oil palm production systems beyond monoculture with agroforestry as the main focus. We visited oil palm agroforestry practiced by smallholders in Jambi and Central Kalimantan and asked questions about their motivation in adopting agroforestry, farm management, value chain and institutions. We found that smallholders have various motivations in adopting oil palm agroforestry but improving their household resilience becomes the most prominent reason. The adoption of perennial species, oil palm and other crops in the farms may improve the diversity of the farms and thus the diversity of household income. However, smallholders encounter problems on productivity because of the competitions in spaces. Lack in the knowledge of species selection, quality of planting materials and spacing arrangement have influenced oil palm productivity. In addition, market access also becomes a crucial issue when their farms are located in remote areas. There is currently no institutions, both government and non-government which promote and facilitate the adoption of oil palm agroforestry although this system has been practiced especially by smallholders. We suggest that oil palm agroforestry system needs to be further investigated not only regarding financial benefits for the smallholders but also its social acceptability and barriers of adoption as well as its potentials in contributing to the improvement of ecosystem functions.

1. Introduction
Oil palm has been seen as the green gold as it contributes to national and regional income generation, job creation and economic growth and its development has been supported by national and regional regulations [1], [2]. It has been rapidly expanding and becoming an important export commodity for the country. In 2016, Indonesia produced more than 31 million tons of palm oil from its 11 million ha oil palm plantations where around 40% of it is managed by smallholders. Around 24 million tons of oil palm was exported with total export value amounted USD 16.27 billion. The whole palm oil production contributed around 13.52% of national GDP [3].

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Most of the oil palm plantations in Indonesia are cultivated as a monoculture. The establishment of these monoculture oil palm plantations has involved the conversion of significant size of land [4] which includes forest lands [5], agricultural lands [6] and peatlands [7], [8]. These land conversions have led to deforestation [5], habitat fragmentation [9], [10], biodiversity loss [11], [12], [13], disturbance on hydrological system [14], land subsidence [15], [16], recurrent fire events and increased GHG emissions [17], [18].

Regions that highly depend on oil palm tend to experience boom and bust economic growth [19] instead of long-term sustainable growth because their growth is subsidized by the exploitation of lands and natural resources [20]. The conversion of diverse land uses into monoculture oil palm plantations has also transformed people’s livelihood and potentially threatened food security [21], [22], [23]. The monoculture practice has created a monoculture livelihood strategy that highly depends on merely oil palm [19] and entails social and economic risks [24]. Forest dwellers have potentially found difficulties to survive because of forest loss [25] as well as have been challenged by increasing competition for lands and the conflicts embedded in it [26].

At the same time, the demand for oil palm products is likely to increase. The Coordinating Ministry for Economic Affairs of the Republic of Indonesia estimated that the growth of demand for oil palm products would continue to grow at about 5% annually [27]. In addition, two major sustainability certifications of oil palm, Roundtable on Sustainable Palm Oil (RSPO) and Indonesia Sustainable Palm Oil (ISPO), also require improvement in the performance of production unit for more sustainable production [28], [29]. Developing and implementing an action plan that supports increasing sustainable oil palm production as well as maintaining and preserving biodiversity are necessary for smallholders under the ISPO principle and criteria 4 and 3.3 for smallholders, respectively. Additionally, long-term livelihood benefits by regularly reviewing the performance of the production unit become requirements for RSPO smallholder standard in criteria 6.3. Those conditions encourage plantation managers to find an alternative oil palm management system. For those reasons, there is an urgency to find alternatives for more sustainable oil palm production to minimize those aforementioned adverse impacts on natural and social systems by promoting more sustainable production of existing oil palm plantations without expanding its area.

In this article, we argue that the monoculture system is not necessarily to be the only way to produce oil palm. Mixed cropping between oil palm and other crops [30], [31] or livestock [32] has been practiced in limited scales. Experiments indicated that the biodiversity enrichment in oil palm plantations with multi-purposes trees species (MPTS) could contribute to the improvements of ecological and social functions of the landscapes [24]. The land sharing in this agroecosystem matrix of agroforestry seems to be a more realistic to promotes the multiple uses of landscapes [33] than land sparing with intensified agriculture [34]. Therefore, this article aims at analysing alternatives for oil palm production systems beyond monoculture with agroforestry practiced by smallholders as the main focus.

2. Methods and analysis
As the oil palm agroforestry has not been widely adopted, the selection of the cases is mainly based on the oil palm agroforestry practice. The selection of the cases was done through a series of focused group discussions (FGD) with key informants. This includes government officials, NGOs and village leaders. We visited oil palm agroforestry practiced by smallholders in Jambi and Central Kalimantan (two cases). Sumatra is an old oil palm region that hosts the oldest commercial oil palm plantation in Indonesia [35] while Kalimantan becomes a relatively new frontier for oil palm expansion in Indonesia [36], [37]. We asked questions about their motivation in adopting agroforestry, farm management, value chain and institutions. This includes the problems they have perceived in managing oil palm agroforestry. The interviews were conducted in a semi-structured nature [38].

The results of the interviews have been employed to describe the existing types of oil palm agroforestry practiced by farmers, the motivation of adopting oil palm agroforestry, the problems related to its management, institution and market of the oil palm fresh bunch fruits.
This article proceeds in three sections. The first section links our field investigation with theoretical consideration of agroforestry, livelihood and conservation. The second section presents examples of agroforestry practices from Jambi and Central Kalimantan that includes the motivation in adopting oil palm agroforestry, farm management and barriers in adopting oil palm agroforestry. The third section offers discussion and conclusion.

3. Agroforestry, livelihood and conservation

Lundgren [39] defines agroforestry as a collective name for land use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined on the same management unit with herbaceous crops and animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions among the different components. Therefore, agroforestry has been considered to contribute to improving the livelihood and ecological resilience [40].

Agroforestry could be established through the integration of trees into farming systems or integration of farmers into forests [41]. The adoption of trees species into agricultural system could improve rural livelihood in the tropics because the function of tree products is ubiquitous in rural livelihoods such as in construction, fencing, furniture, foods, medicines, fibres, fuels and livestock feed, and their cultural value [42]. This way, agroforestry offers an opportunity to diversify sources of household income and more sustainable rural development [41].

In addition, the current expansion of crops such as oil palm in the tropics has replaced a significant size of tropical forests. This has led to habitat fragmentation [12], biodiversity loss [11] increased GHG emissions [17] and land-related conflicts [43], [26]. Agroforestry system has been widely recognized of having potential in contributing to climate change mitigation because of its capacity in carbon storage and sequestration [44]. In addition, the integration of farmers into forest could become an alternative to resolve or mitigate tenure problems in relation to agricultural expansion into forest areas [41].

Moreover, debates on land sharing and land sparing also suggest that the future conservation should be integrated with the agro-ecological matrix [34]. This will become an alternative to land sparing, and intensified agriculture becomes the prominent conservation practices [45] and has led to adverse impacts on livelihood and ecological resilience [40]. Agroforestry might become one of the realistic ways to sustain forest resources in the current situation where the pressure to forestlands has been continuously increasing [46] driven by the process of globalization of space [47].

However, market of commodities is very crucial in influencing farmers’ decision for the adoption of agroforestry system [48]. In other words, the agroforestry landscape should be productive and could offer meaningful financial benefits, social and environmental impact for the households so that farmers will maintain and improve the diversity and the quality of trees species in their farm [49]. Institutional interventions could facilitate to improve the process in farmers decision-making [50] such as in species selection, farm management and marketing of agroforestry products.

4. Practices of oil palm agroforestry

We identified three types of oil palm agroforestry managed by households in Jambi and Central Kalimantan based on the agroecosystem matrix combination in the farm: (a) mixed cropping between oil palm and Shorea spp, (b) mixed cropping between oil palm and sengon (Falcataria molucana), and (c) mixed cropping between oil palm, jelutung (Dyera costulata), rubber and other food crops. This section analyses each type of oil palm agroforestry. The summary of each agroforestry system visited is summarized below.
Table 1. Summary of each agroforestry type

| Information                      | Oil palm & Shorea spp | Oil palm & sengon | Oil palm, jelutung, rubber, and other food crops |
|----------------------------------|-----------------------|-------------------|-------------------------------------------------|
| Location                         | Kuamang Kuning, Jambi | Sei Gohong, Central Kalimantan | Sei Gohong, Central Kalimantan                   |
| Year of adoption                 | 2000                  | 2016              | 2008                                            |
| Area (ha)                        | 2                     | 2                 | 4                                               |
| Motivation                       | Timber scarcity for construction and housing & improve timber self-sufficiency | Decrease of rubber latex price & development plan of new sengon mill | Volatility of commodity prices & improve income stability |
| Land status                      | Privately owned       | Privately owned   | Privately owned                                 |
| Spacing strategy                 | (9x9) meter for OP trees and (3x3) meter for Shorea spp | (9x8) meter with two rows of sengon in between OP rows | irregular pattern with 80 OP trees/ ha          |
| Harvesting of OP FFB             | 700 kg/two weeks      | -                 | 400 kg/two weeks                                |

4.1. Oil palm and Shorea spp agroforestry

Mixed cropping between oil palm and Shorea spp was practiced in SP A, an oil palm transmigration village in Kuamang Kuning, Jambi. The adoption of Shorea spp in oil palm plantations was stimulated by the perceived timber scarcity in the region. The community perceived this timber scarcity because they could not easily find timbers for construction and housing in the region and its price has been steadily increasing. The adoption of Shorea spp was expected to increase timber self-sufficiency, especially for construction and housing. The main current source of household income has been oil palm as their main job is oil palm farmer. The farmer could harvest around 700 kg every two weeks. The farmer joined the oil palm production system through the transmigration programme as a supported smallholder.

This agroforestry farm is located in adjacent to the house. The parcel size is 2 ha, and it was acquired through transmigration programme. The spacing of oil palm trees is (9x9) meter for oil palm trees and (3x3) meter for Shorea spp trees. The integration of Shorea spp occurred when the oil palm trees are already 15 years old. This way, the seedlings of Shorea spp could get sufficient shading from the oil palm, which is necessary for the juvenile stage of Shorea spp. In addition, after 15 years, oil palm trees have reached their peak production phase and the integration of Shorea spp should minimize the nutrient and sunlight competition with oil palm trees. The horizontal projection of the farm is depicted in figure 1.

Figure 1. Horizontal projection of oil palm and Shorea agroforestry
Because he is a supported smallholder, the farmer gained support from the oil palm nucleus company in establishing oil palm plantation. This includes the certified planting materials and in-house training to maintain his oil palm farm. The *Shorea spp* planting materials were also gained from the field research station of Faculty of Forestry, Universitas Gadjah Mada in Jambi which is located near the village. The field research station was a research center for tropical rain forest rehabilitation, joint cooperation research between Universitas Gadjah Mada and *Kansai Electrical Engineering Center* (KEEC) Japan. The farmer who managed this agroforestry farm is a member of a farmer group which has collaboration with the nucleus oil palm company under the nucleus estate smallholder (NES) scheme. Therefore, the harvest of oil palm fresh fruit bunches (FFB) has been sold directly to the nucleus company.

4.2. *Oil palm and sengon agroforestry*

Mixed cropping between oil palm and sengon was practiced in Sei Gohong, Bukit Batu near Palangkaraya, Central Kalimantan. The adoption of sengon in oil palm farm was started two years ago and was stimulated by the continuous decrease of rubber latex price and the rumour about the development plan of the new sengon mill in Pulau Pisa, Central Kalimantan which is hoped to elevate the price of sengon timber. The current income of the household is sourced mainly from rubber and oil palm which have been managed in other parcels. The future incomes generated from sengon timber and oil palm become the household strategy to cope with the loss of income caused by a continuous decrease in rubber latex price.

This oil palm and sengon agroforestry cover 2 ha on a privately owned parcel. This agroforestry parcel is not located surrounding the house such as home garden. The distance of this parcel from the house is around 0.5 km. With this distance, it is handy to have oil palm and perennial trees such as sengon because they do not demand daily maintenance. The spacing for oil palm trees is (9x8) meter. This spacing allows the incorporation of sengon trees in between the oil palm trees. In this case, there are two rows of sengon trees in between oil palm rows. The canopy configuration of the farm is depicted in figure 2.

The oil palm planting materials were obtained from the local market without information on quality assurance or certificate. The farmers do not have access to the knowledge about good quality planting material because the agricultural extension or other sources or agricultural information current do not exist in the region. Besides, the price of oil palm certified planting materials is relatively expensive and most of the smallholders cannot afford it. Similar case also occurred to the sengon planting materials, and even worse because the young sengon trees were destroyed by a group of wild deer. The farmer also uses fertilizer mainly manure and pesticides especially in the establishment stage of the farm establishment.

During the field investigation they were more or less two years old, and therefore oil palm trees were not yet producing fruits, and the sengon trees are expected to be mature at around six years old. So far, smallholders sell their rubber latex and oil palm FFB through middlemen who play roles as collectors. These middlemen collect the rubber latex of oil palm FFB from the farm or along the roads and transport the rubber latex or oil palm FFB. Often, these middlemen also become the investors for the new oil palm plantation. This occurred mainly when the smallholders have limited access to formal financial schemes. The future harvest of oil palm agroforestry and the sengon timber will likely experience similar path of the value chain.

The farmer we have visited has been a member of a farmer group. However, it seems that there are not many activities organized by the farmer group and becoming a member of a farmer group is more administrative than a real need.
4.3. Oil palm, jelutung, rubber, and other food crops agroforestry

In Sei Gohong we also found agroforestry practice which combines oil palm, rubber, jelutung (*Dyera costulata*), *petai* (*Parkia speciosa*), and pineapple (*Ananas muricata*). The spacing between oil palm, rubber, jelutung, and *petai* trees does not follow certain distance, and therefore the spatial distribution of the trees has an irregular pattern. This agroforestry covers around 4 ha private land which located surrounding his house. Although it the size of his farm is relatively large, he manages to do all the work by himself with the help of the family members.

This farmer has been managing agroforestry farm for ten years, but initially, he mixed rubber and jelutung and pineapple. Oil palm trees came later in his farm. It started when the rubber trees were around three years old. Therefore the average age of the rubber trees is around ten years while the age of oil palm trees is ranging from five to seven years. The introduction of oil palm trees into his farm was stimulated by the volatility of commodity prices in the global market and managing only one type of commodity in the farm was perceived as a high risk in term of household income stability.

With this combination of several crops in his farm, he could manage to diversify his household income sources and improve the household resilience. He applies certain yield regulation so that he can manage daily income from various harvests of his farm. This was done by dividing his farm into several blocks of management to regulate the harvests of rubber, oil palm, jelutung and pineapple. He manages to harvest around 400 kg oil palm FFB every week from different blocks alternately. He sells this oil palm FFB for IDR 800 per kg to a middleman who comes to his farm every week.
5. Discussion

From the agroforestry practices aforementioned above, we learned that smallholders have various motivations in adopting oil palm into their agroforestry farm, but the financial benefits in improving their household resilience become the most prominent reason. The price volatility of commodities in the global markets, the decrease of rubber latex price and the increase of oil palm have been stimulating the adoption of oil palm agroforestry. The adoption of perennial species such as *Shorea spp*, sengon, jelutung, rubber, and petai as well as other crops such as cocoa, pineapple and seasonal vegetables in the farms may improve the diversity of the farms. This way, the farmers could diversify their sources of income for the household. It likely the market of commodities play important roles in determining the farmers’ decision in adopting certain species [48] and increase the adaptability of agroforestry.

However, smallholders encounter problems related to farm management. First, the species selection is mainly based on the market instead of the biophysical suitability or combination compatibility. For example, when the price of oil palm increases farmers will likely adopt oil palm and tend to plant the trees in an irregular pattern which could lead to space competitions. This space competition could lead to severe adverse impacts on productivity when the species also compete for the same nutrients. In particular, soil type plays important roles in determining oil palm productivity. A study suggested that oil palm trees planted in mineral soil performed better than those in peat soil [51].

Moreover, farmers also tend to use uncertified or unknown quality of planting materials for perennial plants, oil palm, fruits and vegetables which could also lead to low productivity. This is mainly because farmers do not have access to information about good quality planting materials and farmers do not have resources to access certified planting materials because they are relatively more expensive. In the case of oil palm, farmers often use planting materials which were produced from “brondolan” or oil palm fruits that break away from oil palm FFB. Therefore, the quality of planting materials produced from these fruits is unknown which could lead to low productivity of oil palm. It is quite different with oil palm supported smallholders which gained on the job training from the nucleus companies [35]. For those reasons, it is important to consider the species selection, spacing arrangement and the quality of planting materials to maximize association, minimize competition and improve the productivity of the farm.

The market also becomes a crucial issue especially because agricultural products often experience a very long value chain before they could reach the end consumer. This way, the farmers will gain a very limited margin because they are in the low-end position of the whole production chain. For example, most farmers sell their oil palm FFB through middlemen instead of directly to the oil palm mills. This mainly the case of independent smallholders who have no contract with nucleus companies or oil palm mills, their farms are located relatively far from oil palm mills with poor transportation infrastructures. These situations have led to high dependency on middlemen who become the only connection between farmers and oil palm mills [19].

In addition, access to land resources for smallholders also becoming a crucial issue in the regions because lands become scarce. This is mainly because most lands are already occupied by large-scale licensing for various land-based activities [36]. During the fieldwork, we also observed potential land conflicts in the regions especially related to oil palm expansion into state forest areas. Agroforestry could contribute to solving these tenure problems in the forest areas by integrating farmers into forests which includes the granting of use rights of the forest lands [41]. This will require strong institutions both in the grass root and forest management levels.

There is currently no institutions, both government and non-government which promote and facilitate the adoption of oil palm agroforestry although this system has been practiced especially by smallholders. Farmer groups and extension workers could help in solving asymmetric information such as the quality of planting materials as well as promoting oil palm agroforestry as an alternative to its monoculture intensified management.

We also noticed that the adoption of oil palm in agroforestry had mainly occurred during the oil palm boom. Although we are optimistic that oil palm agroforestry could contribute to improving
household livelihood resilience and more sustainable oil palm production, it was not clear whether oil palm agroforestry will become the permanent land use-cover, or it will be a transient land use/cover before the farmers slowly convert their farms into monoculture oil palm plantations or other types of crops which have more lucrative financial benefits.

6. Conclusion

In this article, we argue that oil palm agroforestry could be an alternative to enhance farmers’ livelihood resilience. We found at two provinces in Indonesia namely Central Kalimantan and Jambi that the most prominent reason of smallholders to adopt oil palm agroforestry in their farms is to improve household resilience especially in terms of income. However, smallholders often encounter problems related to farm management such as low productivity due to poor species selection that are combined in agroforestry. The species selection is mainly based on the market instead of the biophysical suitability or combination compatibility. Farmers also tend to use uncertified or unknown quality of planting materials for perennial plants, oil palm, fruits and vegetables. In addition, farmers gain a very limited margin because they are in the low-end position of the whole production chain. These situations have led to high dependency on middlemen who become the only connection between farmers and oil palm mills. Access to land resources becomes a crucial issue for smallholders because most lands are already occupied by large-scale licensing for various land-based activities. This situation triggers smallholders to occupy state forest areas, which later could become law violation issues. Finally, we suggest that oil palm agroforestry system needs to be further investigated not only regarding financial benefits for the smallholders but also its social acceptability and barriers of adoption as well as its potentials in contributing to the improvement of ecosystem functions.

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