Developing sustainable smallholders of cinnamon by intercropping of patchouli and coffee in Kerinci, Jambi

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Abstract. Cinnamon is one of the spices traded in the international market, Indonesia supplies about 40-50%, and the others come from China, Vietnam, Sri Lanka, and Madagascar. Smallholders mostly conduct the main cinnamon central productions of cinnamon in The Regency of Kerinci, The Province of Jambi, and The Province of West Sumatera. The problem of cinnamon is harvested from the bark, so it should be cut out of the trunk and must wait more than seven years to harvest. In the case of higher prices, it encourages farmers to harvest more rapidly and expand, so that there are extensive planting and encouraging smallholders to extend shifting cultivation, thereby threatening the sustainability of land resources. The review aimed to addressed possibilities in encouraging farmers to plant patchouli and coffee intercropped with the cinnamon trees to sustain the land resources and increase farmers income. Patchouli and coffee are high economic value crops that common cultivated in Jambi Province, patchouli can be quickly harvested and coffee requires shade. The study suggest that using patchouli and coffee in cinnamon smallholders as an intercrop plant is expected to be more sustainable not only from environmental but also from a social and economic perspective.

1. Introduction
Sustainable agriculture is a concept of agricultural production to achieve high productivity, to fulfill the needs of communities and markets by utilizing technology and resources wisely to preserve the environment, improve social welfare and achieve economic efficiency both in the short and long term [1,2]. In its implementation, sustainable agricultural development can change existing agriculture to be more efficient and useful by applying appropriate technology that is environmentally friendly, socially acceptable and economically feasible, while still achieving optimal levels of production. It can also transform a monoculture farming system that use resources extensively for one type of crop to become a more diverse farming system and use resources more efficiently [3,4].

Cinnamon is spice products derived from the bark of cinnamon plants (Cinnamomum sp.), which is used as a flavoring and aroma for food, beverages, and also as a natural medicinal ingredient and perfume, which is traded in the international market as well as in the domestic market. Cinnamon is produced in various countries such as Indonesia, China, Vietnam, Sri Lanka, India, and Madagascar [5]. Cinnamon that circulates in the world market consists of cinnamon China (Cassia), Vietnam (Saigon), Indonesia (Korintje), and Sri Lanka (Ceylon) [6].

According to the FAO report, Indonesia was the largest producer of cinnamon (Cinnamomum burmanii Blume) that produces 46.7% (93,000 t) in 2010 to 2014, which was followed by China (34.2%)
and other countries (19.1%) [7]. In Indonesia, the production of cinnamon is in 19 provinces, but the most substantial producer is in The Province of Jambi, especially in the Regency of Kerinci. According to the Statistics of Estate Crops, the Ministry of Agriculture, the national production of cinnamon in 2018 amounted to 80,617 t, where the contribution of Kerinci amounted to 52,310 t.

The biggest export destination country of Kerinci cinnamon is the United States, which is followed by Europe, Thailand, and India. According to the Agency of Statistics Center, the total exports of cinnamon in 2011-2017 ranged from 53,000 to 65,000 t, mostly from Kerinci and the Province of West Sumatera ranged from 40,000 to 43,000 t. Most of Kerinci cinnamon is exported through Teluk Bayur (West Sumatera) Port. Indonesian cinnamon export products include cinnamon bark, essential oil, and ground cinnamon.

According to information from the Office of Estate Crops and Livestocks of Kerinci, the price of cinnamon at the farmer's level was fluctuating. In 2012 to 2016 the price of cinnamon was very low, less than Rp 5,000 kg⁻¹ and the price increased from 2017 to more than Rp 30,000 kg⁻¹. The regular price of cinnamon ranges from Rp 10,000 to Rp12,000 kg⁻¹. When prices are low, farmers tend to harvest as needed. Otherwise, at high prices, farmers tend to harvest excessively. The economy of Kerinci is also highly influenced by cinnamon prices; when it is high, the economy looks more active, so does the opposite.

The production of cinnamon in Kerinci is carried out by smallholders and in a traditional way. In general, harvesting of bark cinnamon is in a minimum of 8 years after planting and done when farmers need funds, or the price is high. Hence, many farmers do not have other lands, working outside the farm, and many of them become Indonesian workers abroad.

Cinnamon is an export commodity needed throughout the world; however, the farmers got only low income and mostly poor [8]. The contribution of cinnamon income is only 8.86%, caused by long harvest time, narrow land owned by farmers, and the price often decreases. Besides, the harvest is done by logging the whole plant, so that when the price of cinnamon is high, logging is excessively done. After the logging is generally not directly replanted because the seeds are not always available, hence the land is opened, and in turn, the threat of erosion and landslides are very high.

Based on the phenomenon, it can be concluded that the sustainability of cinnamon production is very vulnerable to the environment, social and economic. However, it has a potential market that continually grows because of the broader knowledge about the benefits of cinnamon products, not only as a spice but also developed as a natural ingredient for the pharmaceutical industry.

The patchouli is a plant that produces essential oils that can grow in a short time, and some farmers have already cultivated in Kerinci. Similarly, coffee plants are already well known in this area, and Kerinci coffee is also known as high quality coffee. The review aimed to addressed possibilities in encouraging farmers to plant patchouli and coffee intercropped with the cinnamon trees to sustain the land resources and increase cinnamon farmers' income.

2. Sustainable cinnamon cultivation in Kerinci
The cinnamon plants have several varieties, one of which is the Cinnamon Kerinci or Cassia (Cinnamomum burmanii Blume), which is well-known around the world, alongside the Ceylon cinnamon known as the true cinnamon (Cinnamomum zeylanicum Blume). Planting cinnamon trees does not require specific soil requirements. It can well grow on various soil types, from fertile organic soils to marginal sandy soils. Cinnamon trees' growth can be faster on well-drainage soil conditions, and the yield can be higher. Cinnamon ideally grows in tropical climates, with rainfall of 1,250 to 2,500 mm [9] and altitude of 0 to 1,500 m above sea level depending on the cinnamon species.

To develop sustainable cultivation of cinnamon, besides planting in the right location that has soil and climate suitability, it should also apply the principles of Good Agricultural Practices (GAP). In general, the principles of GAP are the use of qualified seeds, applying the right soil and water management, planting pattern, and pest and disease control. These principles are involved in the perspective of maintaining environmental equilibrium, improving the farmers' welfare, and income in the long-term [10].
2.1. Qualified cinnamon seeds

Qualified seeds must be derived from suitable plant materials. These superior varieties of C. zeylanicum, called Zeyna Agribun 1 and Zeyna Agribun 2 have been released and recommended by the Ministry of Agriculture, and multiplied according to the recommended seed production procedures [11]. Farmers generally conduct replanting after harvesting or new planting using available unselected planting materials from surrounding areas. It happens because the hitherto Ministry of Agriculture is still conducting selection to release superior varieties for species of C. burmanii.

The Government of Kerinci has made endeavors to conduct the selection of plants in various locations to determine selected parent trees as sources of seeds, although still in limited quantity compared to the need. The demand for qualified seeds was very high because of the increase in new planting areas. According to information from the Kerinci Government Office of Plantation and Livestock, the cinnamon area in Kerinci was about 53,000 acres in 2019, increased from 46,000 acres in 2016 that suspected because of the significant price increase since 2017 if it was assumed that the need of seeds 1,200 per acres, hence total needs for 2016 to 2019 were 8.4 million.

Sustainable seed supply can be realized only when seed production is implemented as a profitable business. Hence it should be developed seeds institution. Seed institution mainly consists of two parties, seed producers and government. Seed producers are profit-oriented business institutions, and then the seed producers will see when and how many seeds are needed to prepare seed production to supply in the right quality, time, quantity, and price. The role of the government is as supervisor of seed production and distribution and also as the facilitator in supplying suitable plant materials. Besides, farmers can prepare seeds independently. Therefore it is required technical guidance of seeds production to make the sources can meet the quality standard.

2.2. Soil and water management

Soil and crop management has a vital role in soil maintenance and improvement because of its direct influence on the structure and habitats of the microbiota. The soil management system is a primary contributor to the economic and environmental sustainability of agricultural production [12]. Some soil preparation techniques can be applied to protect the soil from erosion and degradation of soil quality, such as no-tillage and leaving the residue of the plants in top soil [13]. The techniques applied in soil preparations have a direct effect on the quality of soil, then associated with economic, social, and environmental sustainability, both short-term and long-term [14]. Farmers can adopt requirements that must be fulfilled for a technique is cost-effectiveness, increase in yield and income, and improve soil conditions [15].

The topography of the Kerinci region is mostly mountainous because it is located in the area of Mount Kerinci. However, there are cultivation areas with a slope of less than 15% that is used as rice fields (food crops), and the others mostly use for plantation such as coffee, rubber, and oil palm. Consequently, conservation tillage should be applied to reduce erosion and soil quality degradation. Conservation tillage is the tillage, which leaves a minimum of 30% residue plant after harvest is carried out [15]. The choice of techniques that can be applied is no-tillage, ridge-tillage, mulch-tillage, and other tillage that leave 30% of the residue of plants. The application of no-tillage is to let the soil surface not to be disturbed, except for fertilization and drilling pits. Ridge-tillage is one of the standard conservation tillage systems that usually use for planting on the ridge. At the same time, the mulch-tillage is applied when the surface has been disturbed on the previous planting. Residue plant is maintained at the soil surface [16]. Cinnamon is a woody perennial-crop; therefore, all the techniques of conservation tillage can be applied.

In sustainable soil fertility management, the main principles are the soundness of ecological impacts and the cost-effectiveness of the actions taken. Generally, to improve and maintain soil fertility, the easiest way is to use in-organic fertilizers manufactured, but this is not following the principle of sustainable soil fertility management. The use of low input in sustainable agriculture is one of the method that is in line with the principles of sustainable soil fertility management, to optimize the use of internal inputs and reduce external inputs such as the use of fertilizers and pesticides, so that production
costs and ecological impacts can be reduced, which can ultimately increase the profit in the short and long term. Internal inputs are natural resources (soil, water, microbes, plants, and animals) and human resources (labor, knowledge, and skills) that locally available [17]. Because cinnamon farmers' condition in Kerinci is mostly low income, the method of low external input sustainable agriculture is suitable.

Cinnamon is a rainfed crop; therefore, activities such as land clearing, seedling preparation, planting, pruning, and harvesting should be adjusted to the rainfall pattern along a year. Rainfall in Kerinci averages 180 mm per month, with a dry month for four months, June-September. The beginning of the rainy season is an excellent time for seed preparation and planting, the end of the rainy season for pruning and harvesting, and the end of the dry season for land preparation. Soil and water conservation must be done to ensure the long-term sustainability of agriculture. Climate change can result in changes in agricultural management, especially in rainwater management; therefore, productivity does not become vulnerable [18].

2.3. Planting pattern
Most farmers grow cinnamon in monoculture and could be harvested after eight years. Therefore, during waiting for the harvest, some farmers mainly do not own other lands, looking for other jobs, such as traders or labor. These conditions make cinnamon plantations become economically and socially unsustainable. Cinnamon on monoculture pattern is mostly planted in high density at first, amount 2,500 to 3,000 seedlings per acres, and gradually decrease to 180–300 trees per acres in the seventh year [19]. It aims to push stems that can vertically and straightly grow at the beginning of growth. If the stems have reached an average height of 2-3 m or in 2-3 years old, then density reduction is made to encourage the horizontal growth until the first cut in the seventh year or after that.

The development of polyculture planting patterns is a solution that can provide continual income [20]. Ideally, the planting pattern applied is a combination of annual and perennial crops; therefore, it can also avoid extensive farming and shifting cultivation. Some farmers have implemented polyculture planting patterns such as farmers who are in upland, by growing upland rice or other annual crops and coffee. For rice and other annual crops can only be in the first two years after cinnamon planting.

Most farmers apply to plant patterns with a composition between cinnamon and coffee are 6:1 and 3:2. For annual crops other than rice, patchouli (Pogostemon cablin Benth.) that produce essential oil is most planted, especially at times of low cinnamon price. Coffee is a shade plant that can be grown under cinnamon and used as a diversified plant to avoid deforestation in Panama [21]. In Kerinci, coffee is the second tree plant after cinnamon, both Arabica and Robusta coffee. Arabica coffee from Kerinci has obtained Geographical Indication Certificate 2017 under the name Kopi Arabika Sumatera Koerintji; hence it has established an export market.

2.4. Harvesting
Sustainable management of cinnamon is necessary to set harvest times that are adjusted to the growth rate and lifespan of the plant. In Sri Lanka and India, the harvest of cinnamon bark is carried out in the second or third year after planting and harvested every 12 to 18 months after the previous crop. The plants are not cut down. Cutting is done in the middle of the branch to obtain bark with 1.0-1.25 m length and 1.25 cm diameter to get the best quality [22].

The harvest of cinnamon in Kerinci is different from in Sri Lanka or India. In Kerinci, two methods carry out the crop, first carried out after the plant is 7-10 years old, preceded by pruning at the age of 2-3 years after planting to foster the growth. The first harvest is done by scalping the bark with 7-8 cm width and 80-100 cm height. Harvesting is generally done not in flowering times (at the beginning of the dry season) because peeling is easier to do. The second method of harvesting is conducted by cutting down the whole tree at the age of more than ten years, then immediately peeled in the field. The quality of the bark of older trees is better because it is thicker and to be peeled with a thickness of about 2.5 cm, while the bark of younger trees is generally used as sticks [7].
If it is benchmarked, cinnamon harvesting patterns conducted in Sri Lanka and India are more sustainable than in Kerinci from environmental, social, and economic perspectives. The harvests in Sri Lanka and India are carried out every 12-18 months, much shorter than seven years in Kerinci. From the environmental aspect, the crops that have a higher population density tend to low erosion, and if it is harvested more frequently, the products tend to be higher. Consequently, farmers' incomes would be higher. In the next new planting and replanting, programs can be introduced to farmers the planting pattern with shorter harvest time.

2.5. Processing and grading
After the barks were scalped, then washed and soaked for one night to be cleansed from dirt, direct sun-drying was carried out for 3-4 days to avoid contamination of fungi and other contaminants [7]. In general, the process of cinnamon is done by farmers only the initial drying, then next processed into quills and sticks to adjust the market demand, and collectors or exporters carry out grading. Even some farmers sell trees directly in the field, while collectors or exporters carry out harvesting and processing.

To make the cinnamon production in Kerinci become more sustainable and increase farmers' income, there are Government programs to improve added value through advance processed products become final and branded products like sticks, syrup, and ground cinnamon.

3. Intercropping patchouli and coffee
As the cinnamon production in Kerinci applies monoculture planting patterns; hence it has to wait a minimum of 8 years for the first harvest, and the farmers' income becomes non-continuous. Many farmers look for work outside the agricultural sector after planting to obtain alternate payment, especially farmers who do not own other lands. The development of polyculture planting patterns is an alternative solution that makes cinnamon production can be more sustainable. By referring to the crops that have been cultivated by farmers in Kerinci and surrounding areas, coffee and patchouli (producing essential oils) become alternatives as intercrops of cinnamon cultivation.

Coffee is a perennial crop that can produce in 3-4 years after planting and harvested every year, while patchouli is an annual crop that can be harvested in 6 months after planting and then after that harvested in every 3-4 months until the age of 2 years. Coffees in Kerinci consists of arabica coffee in the highlands and robusta coffee in the lowlands. In general, cinnamon is cultivated in the lowlands. Still, there are also those in the highlands, so the choice is according to the location of the land, while patchouli can grow in lowlands and require open and relatively flat land (the slope is less than 15%).

3.1. Coffee
Coffee cultivation for farmers in Kerinci has become a common livelihood. The farmers that live in the region with an altitude over 1,000 m above sea level, generally cultivate Arabica coffee. Kerinci arabica coffee is well-known for its high taste. It has been obtained a geographical indication certificate from the Ministry of Law and Human Rights in 2017, No. 2/IG/XI/A/2017, under the name of Kopi Arabika Sumatera Koerintji. The Official News of Geographical Indications mentioned that the results of the analysis conducted by the Coffee and Cocoa Research Center, it is known that the quality and taste of Koerintji arabica coffee includes specialty grade with a score of >84. Aroma characteristics (fragrance), flavor, acidity, and viscosity (body) are excellent with a value ranging from 7.75-7.88 and provide a perfect sweetness with a value of 10.0, which is accompanied by the flavors of chocolate, caramelly and lemony. For farmers that lived at an altitude less than 1,000 m mostly they cultivate robusta coffee that dominantly cover coffee in Kerinci. If the total area of the coffee plant in Kerinci is 8,622 ha in 2019, then robusta coffee is approximately 75-80%.

Like a plant that needs shade, coffee is very suitable as a side plant of cinnamon on the same land. Planting patterns with mixed crops can improve the sustainability of cinnamon production, both economically and environmentally [23]. From an economic perspective, intercrop of coffee, plants can diversify cinnamon plants as an added source of income. Besides, because coffee can produce faster than cinnamon crops, payment can also be obtained by farmers before cinnamon.
environmental perspective, polyculture cultivation can increase biodiversity in the field and reduce erosion.

In general, coffee productivity, like other plants, is influenced by the use of technology such as superior seedling, pruning, fertilization, maintenance of shade plants, irrigation, and pest and disease control. The selection of technology for the implementation of these factors should refer to three perspectives of sustainable agriculture, namely environmental, social, and economic. Among the most critical factors are superior seed selection, irrigation, and control of major pests and diseases. The superior seedling selection criteria are productivity, quality of coffee produced, and resistance to major pests and diseases, for areas with extreme climate, additional considerations such as adaptation capacity to dry climates. Coffee seedlings are generally used in vegetative propagation such as grafted seedlings. The root stock materials must have strong rooting systems and resistant to soil nematodes, whereas the upper part (scion) must have higher productivity and quality, as well as resistance to leaf rust disease.

To increase the infiltration of rainwater can be made pits that are filled with compost that also serves to increase the aeration of rooting and organic fertilizer sources. In the dry region, it is necessary to add mulch to reduce evaporation and keep the moisture on the soil surface. Farmers need coaching to increase the adoption of conservation and sustainability-oriented technologies in the long term. Farmer organizations must be strengthened to address problems from upstream to downstream.

There has been Indonesian Sustainable Coffee (IS-Coffee) Certification scheme initiated by the government as an alternative to coffee certification conducted by the Non-Government Organization (NGO) from abroad. The implementation of this certification has not been effective because of limited coordinaion between the government agencies in the region and the center. Also, coffee has not been able to address the problems that exist in smallholders, such as direct access to the market, lack of capital, and farmer organization [24]. However, certification is a strategy to improve smallholder productivity, at least by using the experiences of Fair Trade Certification [25,26].

3.2. Patchouli

Patchouli is an essential oil-producing plant that has high economic value. The oil is used as a fixative ingredient in the perfume industry. The development of patchouli in Indonesia has been widely cultivated, with one of its central areas is the island of Sumatra. The location of the patchouli plantation in Jambi Province is at 1,702 acres with patchouli oil production reaching 295 t and is a smallholder plantation [27]. In general, patchouli is cultivated monoculture and carried out with a moving farming system, making it less environmentally friendly.

As an annual plant that is generally planted monoculture, patchouli grow well in low to medium lands and require medium to full light intensity to grow optimally. Patchouli can be harvested at the age of 6 months after planting and then can be harvested every 3-4 months again, making it suitable as a cash crop and has the potential as an intercropping plant with coffee and cinnamon on low to medium altitude land. Patchouli can be planted among the young cocoa plant without affecting the main crop growth [28]. Research on patchouli conducted on the East Coast of Andhra Pradesh as intercrops in coconut groves, could provide additional income with the value of B:C ratio 2.48 [29], in other cases patchouli as intercrops plant provide additional income with the value of B:C ratio 3.26 under Brahmaputra valley region of Assam [30]. Intercropping system between cinnamon, coffee, and patchouli have the potential to be an alternative income for farmers when coffee and cinnamon cannot yet be harvested, and it can overcome patchouli cultivation with a moving farming system so that it is more environmentally friendly.

In general, patchouli productivity is influenced by many factors, especially factors in cultivation techniques such as superior seedling use, planting, fertilization, maintenance, and handling of pests and diseases. The use of excellent seeds can increase production based on the excellent properties of the source as well as its resistance to specific plant diseases. 5 superior seeds have been issued by the Ministry of Agriculture, and each variety has its advantages [31]. Patchouli seedling is generally multiplied vegetatively through a set of shoots and stems cuttings.
Also, patchouli includes plants that are responsive to fertilization, especially to nitrogen \[32\], so that balanced fertilization can increase the efficiency of fertilizer use. The application of Good Agricultural Practice (GAP) is the main key to improving the productivity of patchouli from an environmentally perspective on smallholder plantations as found in Permentan no. 138 of 2014 concerning GAP of patchouli.

4. Conclusions
Cinnamon cassia from Kerinci is a spice product in the form of sticks and ground cinnamon traded in international markets primarily in the United States and Europe. The development of sustainable cinnamon smallholders needs to be conducted to address the problem of harvest waiting times for seven years. In the time, farmers cannot earn income from the farms. Also, the price of cinnamon fluctuates.

Therefore, at low prices, farmers tend to let it or harvest as needed, while when high prices, farmers tend to harvest out extensively. One way to solve the problems is by planting intercrops between cinnamon plants, mainly by annual crops that quickly produce such as patchouli and perennial crops such as coffee that farmers are accustomed to growing in Kerinci and surrounding areas. Through intercropping, it is expected that cinnamon smallholders will be more sustainable not only from an environmental but also from a social and economic perspective.

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