Developing sustainable pepper smallholders in the East Luwu regency, South Sulawesi province

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Abstract. Sustainable agriculture aims to improve productivity, conserve the environment, promote social welfare, and improve economic efficiency. The productivity of white pepper smallholders in East Luwu Regency, South Sulawesi, was the highest in Indonesia at 1.4 tons/ha, and some smallholders reached more than 6 tons/ha. This research aimed to study the cultivation practices and evaluate sustainability from an environmental, social, and economic perspective. The method used in this research was a case-study on accomplished smallholders in Ranteangin Village, Towuti District. Pepper smallholders’ outstanding cultivation practices that threaten sustainability from environmental and social perspectives were clean land clearing, monoculture planting pattern, utilization of wood supports, clean weeding, and processing. While from an economic perspective, most cultivation practices were sustainable because the higher cost incurred can be offset by higher productivity. Strategies to develop sustainable cultivation practices are implementing more appropriate technologies such as minimum tillage application, multispecies planting of cover crops, live tree supports, and waste treatment in product processing.

1. Introduction
Sustainable agriculture sees agriculture as sustainable activities to produce food, feed, clothing, and energy that should meet the needs of the earth population that always grows. After World War II, the needs increase in line with population growth. Currently, conventional farming refers to various efforts to increase agricultural productivity by applying technologies in the form of superior seed, fertilizer, chemical pesticides, or irrigation [1]. The technology used in conventional agriculture further emphasizes productivity and efficiency, rather than its impact on the physical and social environment. Consequently, sustainable agriculture requires some corrections or adjustments.

There are two views on developing sustainable agriculture. First, by improving conventional agriculture or improving the current cultivation and overcoming the negative impacts and second, by fundamental changes through developing environmental and social friendly technologies. Thus, sustainable agriculture is a productive and friendly farm from environmental, social, or economic perspectives [2].
From the environmental perspective, sustainable farming should implement technologies that can conserve land, water, or organism resources; and avoid applying technology that can degrade resources in both the short- and long-term objectives. The application of technologies merely aimed to achieve high productivity, sometimes ignoring the long-term conservation of resources such as excessive use of pesticides and chemical fertilizers. It can imply a degradation of environment quality like increasing greenhouse gas emissions and pollution, reducing biodiversity, degrading soil quality, declining populations of insect pollinators, and rising human health risks [3].

From a social perspective, sustainable agriculture applies appropriate technologies that do not lead to social conflict. Sometimes, some technologies are exclusively accessed by a specific layer of society. Thus, the technology in question should make more use of internal resources available in farming. Conventional agriculture often ignores the potential of the internal than the external ones. Internal resource usage can encourage the utilization of organic fertilizer and pesticides processed in a farmers’ group. In addition, farmers can also use biological agents produced by groups for controlling pests and diseases of pepper plants, such as endophytic bacteria to control nematodes rather than chemical pesticides like carbofuran [4].

From an economic perspective, sustainable agriculture should refer to economic principles that are achieving efficient farms. High productivity farm is required, particularly to pursue the growing needs of agricultural products, minimize extensive land use, and avoid deforestation. The efficiency of production should be achieved by minimizing production costs. Substitution of expensive external inputs like chemical fertilizers using internal inputs like manure can increase sustainability from an economic perspective [5].

Pepper farms in Indonesia are mostly smallholders (96%). It was experiencing area growth of 2.6% per year in 2014-2017, then being 0.83% in 2017-2019. The rapid growth in the prior period might be affected by the high average price of pepper at the time that is USD 8,100 per ton. In the next period experienced a significant decline, to be USD 3,202 per ton. The area in the year 2019 reached 180,926 ha with a production of 87,152 tons.

The Province of South Sulawesi is one of the contributors for national pepper production with a 7.3% average contribution (2015-2019) with an area of 18,378 ha area and 6,663 tons production (2019) [9]. The largest pepper area in The Province of South Sulawesi is in The Regency of Eastern Luwu. The area growth was higher than the national growth; hence the pepper area was 5,870 ha in 2018 and 3,273 ha in 2013. As a new pepper plantation area, plantation performance is better than other areas, especially in The District of Towuti. The plant canopy diameters reach more than 1.2 m. The height reaches 5 m (with the dead support) as well as its productivity of some farmers can reach 6 tons/ha of white pepper (average of pepper productivity in Indonesia 1.2 tons/ha). The planting and maintenance are very intensive and tend to be more capital used compared to other areas.

Pepper (Piper nigrum L.) is a perennial and vine plant that is classified in the family of Piperaceae. There are many species of Piperaceae, mostly originating from India. The vine consisted of segments with a length of 4-7 cm. The height of the vine depending on the height of supports. For the dead support, generally about 3 m, and live or tree support, it can reach 8 m. There are other two types of vines (shoots) besides climbing (orthotope) vine, ground shoot that can spread on the ground surface, and hang shoots that hang down over the climbing vines. Climbing vines can form 2-3 new branches (plagiotropic vines) as generative branches by cutting. The plant uses the immersed roots of nodes on the ground to absorb nutrients, while for sticking to the climbing pole, it uses the roots above the ground.

Pepper cultivations in East Luwu use higher inputs than other regions in South Sulawesi, even Indonesia. It affects the sustainability of farms from all aspects [6]. This research aimed to study the cultivation practices conducted by the pepper smallholders in East Luwu and evaluate the impacts of pepper cultivation practices on sustainability from environmental, social, and economic perspectives; and develop a strategy to accomplish the sustainable pepper cultivation practices.
2. Methodology

2.1. Research methods
This research was conducted in June 2019 in The Regency of East Luwu (The Province of South Sulawesi), especially in Ranteangin Village, Towuti District. The selection of study area based on productivity and pattern practices of cultivation criteria. The productivity was the highest in Indonesia. There is a farmer who has higher productivity achievement in the region, which was awarded by the International Pepper Community (IPC) as the Best Farmer 2016 and crowned as Accomplished Farmer 2018 from the Directorate General for Estate Crops, Ministry of Agriculture. The productivity was more than 6 tons/ha, far exceeding the national average (1.2 ton/ha) and the average of East Luwu (1.4 ton/ha).

A research method use case-study, which is a qualitative research method to acquire a profound knowledge of unique conditions or events that occur in a region, individual, group of people, or institutions (organization) [7][8]. According to [9], a case study is an ideal method for conducting research requiring a holistic and profound observation of an object, one of which to describe contextually in life.

In the context of farm sustainability, it was used participative case-study to observe the interests. Case-study is not a sample study as research using statistical methods. Hence the selection of object should be with strong reasons. Generalization of case study research results is conducted through analytic generalization, which is different from statistical generalization.

2.2. Data collection methods
The participative observation was conducted to obtain data and information observed while participating in the cultivation, maintenance, harvesting, and pepper processing in the field. To obtain more in-depth information, we conducted interviews using a questionnaire with some farmers. Triangulation across the respondent method was applied to check the reality of data and information obtained [10]. Preliminary data and information related to pepper smallholders were obtained from the Eastern Luwu Office of Agriculture.

2.3. Methods of analysis
The sustainability evaluation of the pepper smallholders was based on the perspective of environment, social, and economy. Each perspective has indicators as a basis in obtaining data from the relevant sources [11]. By adapting [12] that identified the sustainability indicators of pepper smallholders in Eastern Kalimantan region, with some adjustments, the indicators from (1) environmental sustainability perspective are soil erosion, water drain, pollution and biodiversity loss, (2) social perspective is employment opportunity, cooperation opportunity and social cost, and (3) economic perspective is productivity, total cost, and profitability. The cultivation and marketing activities evaluated from these three perspectives can be analyzed step by step from land preparation, planting, maintenance, harvesting, and post-harvesting.

3. Practices of pepper cultivation and marketing
Pepper cultivation and marketing practices of smallholder farmers in The Regency of East Luwu consisted of land preparation, planting, maintaining, harvesting, processing, and marketing (Figure 1).

![Figure 1. Activities of pepper cultivation, harvesting, processing, marketing](image-url)
Land preparation consists of land clearing, plant seed, climbing pole, and drainage development. While planting includes activities of support erecting, seed preparation, and planting the seed. In maintenance, farmers conduct fertilizing, water management, weeding, pest, and disease controlling.

3.1. Land preparation and planting
Generally, the topography in Eastern Luwu is hilly and even bumpy, while most land clearing for pepper cultivation was clean, without any trees left. Besides that, soil treatment is mainly done by the manual excavation of planting and erecting wood support pits. Pepper is known as a non-woody plant with a thin diameter of vines. The roots do not widely spread out. Therefore it is not strong enough to withstand the top-soil from erosion during rain. As it is known that rainfall in the District of Towuti very high, the average of 2017 and 2018 was 3102 mm per year (Agency of Statistical Center of Eastern Luwu). Drainage was developed to hamper rain-water flow and avoid top-soil nutrients washing and erosion. The monoculture planting pattern with wood supports (poles) was mostly applied, plant population density is less than 1800 plants per ha, and the height of support is about 5 m. The population density commonly used in Indonesia at various regions was more than 2000 plants per ha, with a support height maximum of 4 m. The higher population density showed the spirit of smallholders to obtain higher productivity.

The pepper seedlings used in Eastern Luwu are mostly seedlings derived from ground shoots instead of climbing vines that are mostly used in other areas. If the climbing vines are used as a plant material, then new plants directly become the normal plants in the sense that it can form branches of fruits. In contrast, if the ground shoots used, the fruit branches are not formed, therefore in 6-8 months after planting or the plant height about 80-100 cm, the plants should be circularly re-immersed 10-15 cm into the ground around the wood supports. After 2-4 weeks, each node immersed grew to become new climbing vines and followed by fruit branches. From several climbing vines that appear, farmers selected the most productive ones. The cultivation system that uses ground shoots as materials by direct planting was practiced in some of the traditional pepper areas, such as in Lampung and Bangka Belitung. This way is not used in pepper seedling development programs. The government programs use climbing vines to produce mass qualified seedlings [13][14].

3.2. Maintenance, harvesting, processing, marketing
Fertilization is conducted using organic fertilizer (chicken manure) at the dose of 300 sacks (20 kgs/sack) per ha applied twice a year; at the beginning and end of the rainy season. Farmers do not use Inorganic fertilizers. In other areas, it generally only relies on inorganic fertilizers; consequently, in the long-term fertilizing response becomes less meaningful to increase productivity [15][16]. The use of organic fertilizers can improve soil fertility and enhance its water holding capacity and improve soil texture and structure. The chicken manure for pepper fertilization is common utilized in East Luwu. The supply comes from poultry farms in surrounding areas.

The water arrangements are mostly carried out by constructing drainage channels in rows and circumferences while increasing water infiltration is minimal. As in 2015, the plants suffer water shortages in a long dry season but mostly still alive, possibly because of organic fertilizer application. Water infiltration is also increasingly reduced as a result of clean weed control. To increase water infiltration, some farmers apply Arachis sp. as cover-crop that can also function for top-soil conservation, reduce erosion, soil nutrients washing caused by rainfall. According to [17]. Arachis sp. is a source of feed for pepper pests as natural enemies (increasing the population of parasitoids).

The main pepper harvesting took place from September to October, two months later than Bangka Belitung or Lampung regions, because of different climatic patterns around the Lake of Towuti. Harvesting was carried out manually by hired-labors, generally from surrounding districts. Pepper in the East Luwu area is mostly for white pepper. The fruits picked are full-ripe with red color. After harvested, the pepper is sacked and soaked in water until the outer skin is soft in 8-10 days and can be washed then dried with the sun. Some elements such as Fe, Pb, or V are influenced by processing. The hygiene during processing should be controlled, mainly if the pepper will be further processed like grinding into powdered pepper, the higher chances of increasing Pb element [18].
Some farmers sell their products directly to exporters in Makassar, especially for farmers who have pepper plants in more than 2 ha, otherwise mostly sold to local collectors that come to farmers. The exporters are generally representatives of Jakarta and Lampung trading companies, so East Luwu pepper exported from there.

The government expressed the desire to export from Makassar, but the quantity was not adequate. The quality of pepper produced by farmers has to be reprocessed and mixed with pepper from other regions to obtain the required export quality. Exporters do sorting to separate the light berries and redrying to achieve moisture of 12%. Original quality from farmers, the moisture is more than 13% because it only relies on the drying of direct sunlight (traditional way) [19]. The efforts to fulfill desired bulk density as the main requirement of export quality.

4. Impact assessment and improvement strategy

4.1. Environmental perspective

Agricultural activities, as well as other natural resources, use activities, have potential environmental impacts. The main environmental potential impacts of plantation activities (pepper cultivation) are soil erosion, ground-water drain, land, water, air pollutions, and biodiversity loss. Farmers should minimize the potential impacts of realizing sustainable pepper cultivation by applying appropriate land preparation practices, planting, maintenance, harvesting, and processing (Table 1).

Generally, cultivation land in East Luwu changes from other crops or forest land conversion. Land preparation is implemented by totally cleaning vegetation. This practice has potential impacts on increasing soil erosion and water run-off, and degraded biodiversity; hence, greenhouse gas emissions (GHG) are increasing. In the long run, without any effort to control, the soil quality will degrade. This condition is exacerbated by clean weed control so that most of the ground surface is without protection. There are two techniques for improving soil quality, soil amendments, adding materials to soils, and phytoremediation through plants.

**Table 1.** Potential impacts assessment of pepper cultivation, harvesting, processing, and marketing activities to its sustainability from an environmental perspective

| Activities       | Outstanding practices | Soil erosion | Ground-water drain | Pollution | Biodiversity loss |
|------------------|-----------------------|--------------|--------------------|-----------|------------------|
| Land preparation | Clean land clearing   | Higher, threat | Higher, threat     | Higher, threat | Higher, threat   |
| Planting         | Monoculture, wood supports | Higher, threat | Higher, threat     | Neutral   | Higher, threat   |
| Maintenance      | Organic fertilizer use, clean weeding, ditch drainage | Higher, threat | Higher, threat     | Lower     | Higher, threat   |
| Harvesting       | Manual picking        | Neutral      | Neutral            | Neutral   | Neutral          |
| Processing       | Soaking in the side of the river reservoir, sun drying | Neutral      | Neutral            | Higher, threat | Neutral          |
| Marketing        | Indirect selling to exporters | Neutral      | Neutral            | Neutral   | Neutral          |

Additionally, organic matter to the soil can improve soil properties and workability because it can enlarge water absorptive capacity and influence water contents for tillage [20]; hence, it can be used as soil amendment techniques. To improve soil quality, particularly protect topsoil from erosion and
nutrient cleaning, multispecies cover cropping is the most popular method because of the many environmental benefits compared with one or two species cover crops.

Monoculture planting has the potential impacts of increasing erosion and runs off significantly when it is heavy raining. Moreover, it will threaten biodiversity degradation on the land with a slope of more than 15%. The use of wood supports instead of trees further exacerbates the condition. In the long run, it threatens pepper sustainability, so it is advisable to replace wood support with live tree support, such as *Gliricidia maculata* and various trees available in the local field. *Gliricidia maculata* has a function as supporting live pole for pepper and as shade and legume that can contribute fertilizer from nitrogen fixation. This condition is slightly helped by adding organic matter in the pits; hence local water absorption around the plant increases. This organic matter does not cause pollution and greenhouse gas (GHG) emissions as in the use of chemicals in conventional agriculture.

It is soaking in the riverside water reservoir of the sacked harvested berries in 8-10 days until the outer skin becomes soft produce organic waste that causes water and air pollution if there is not any waste processing. This process will secrete foul-smelling gases and water pollutants that directly flow to the river. In addition, the riverside water reservoirs are the common use; hence installation of waste processing should be conducted by the community involved. The government's role is required to provide technical assistance and pilot program because it will threaten pepper cultivation sustainability in the long run.

### 4.2. Social perspective

The impact of pepper cultivation smallholder activities on social welfare is an essential determinant to its sustainability [21]. Social welfare has a broad dimension; therefore, it is selected three factors that are predicted to be the main indicators, namely employment opportunities, cooperation opportunities, and social costs (Table 2).

| Activities         | Outstanding practices                  | Employment opportunity | Cooperation opportunity | Social cost         |
|--------------------|----------------------------------------|-------------------------|-------------------------|---------------------|
| Land preparation   | Clean land clearing                    | Higher                  | Higher                  | Higher, threat      |
| Planting           | Monoculture, wood supports, direct planting | Lower                  | Lower                  | Higher, threat      |
| Maintenance        | Organic fertilizer use, clean weeding, circumference, drainage ditch | Higher                  | Higher                  | Higher, threat      |
| Harvesting         | Manual picking                         | Higher, better          | Higher, better          | Neutral             |
| Processing         | Soaking, sun drying                    | Higher                  | Higher, better          | Higher, threat      |
| Marketing          | Indirect selling to exporters          | Higher                  | Higher                  | Higher, threat      |

Most land preparation activities positively impact social welfare, except land clearing can increase rain-water flow on the surface soil and flood lower areas. It will threaten smallholder sustainability because, in the absence of a complete solution, it will incur a higher social cost (externality) that becomes a social burden in the long run. The practices of pepper planting that is implemented in general, have a low impact on the sustainability of pepper smallholders. Particularly, it has the potential impact of...
increasing social costs related to the use of wood supports logging from forests that has to be usable at least in 10 years, hence it is necessary to be aware of the potential for flooding in the area where the wood is felled. Farmers have to replace the wood support with live tree support to avoid the poor impact of clean land clearing and wood support utilization.

Direct planting that utilizes ground shoot seedlings could lower employment and cooperation opportunities than indirect planting that use vine seedlings in polybags. Producing the later seedling required selected plant material propagation, maintenance, and distribution. Hence it opens job and cooperation opportunities to improve farmers' knowledge by mutual learning to foster sustainability. However, direct planting still supports smallholder sustainability.

Maintenance practiced has entirely supported sustainability from the aspect of improving social welfare. The relatively extensive use of organic fertilizer has encouraged cooperation with many chicken farmers from the surrounding districts. Chicken manure that naturally wastes can be utilized as fertilizer that creates higher value for surrounding communities. Intensive weed, pest, and disease control is done manually. Hence it opens employment opportunities to the community.

In the processing activities, soaking pepper berries in a soaking pool beside the river that directly dispose of waste to the river require installing communal waste processing. Farmer organizations operationally manage this installation to avoid the social cost that potentially occurs in the long run.

Most farmers sell dried white pepper produced to local collectors then forwarded to exporters in Makassar. The problem is in the determination of price, it depends on international pepper price that always fluctuates. Hence the farmer's income becomes uncertain and ultimately affects to farmers' welfare. This situation requires government policy to minimize the social cost that is incurred.

4.3. Economic perspective

Clean land clearing was not only costly but also reduce productivity. The increase in soil erosion and nutrient washing ultimately threaten sustainability. The application of environmentally friendly and cheaper practices such as minimum tillage and land clearing can increase productivity and profit [36].

**Table 3.** Potential impacts assessment of cultivation, harvesting, processing, and marketing activities to its sustainability from an economic perspective

| Activities       | Outstanding practices          | Productivity  | Total Cost     | Profitability       |
|------------------|--------------------------------|---------------|----------------|---------------------|
| Land preparation | Clean land clearing            | Higher        | Higher         | Lower, threat       |
| Planting         | Monoculture, wood supports     | Lower         | Higher, threat | Lower, threat       |
| Maintenance      | Organic fertilizer use, clean weeding, circumference drainage ditch | Higher | Higher | Higher |
| Harvesting       | Manual picking                 | Higher, better| Higher, better | Neutral             |
| Processing       | Riverside soaking, sun drying  | Neutral       | Lower          | Neutral             |
| Marketing        | Indirect selling to exporters  | Neutral       | Higher         | Uncertain           |
Intensive pepper cultivation practices implemented in Eastern Luwu are all aimed to foster crop productivity, it was proven that the productivity achieved by pepper growers in Eastern Luwu is the highest in Indonesia. Nevertheless, the practice of intensive cultivation has consequences of increased costs, so there is a risk if the achieved productivity is not as expected, because besides depending on the intensity of crop management, it also depends on the climate conditions and other factors.

One of the planting practices that should be of concern is the use of wood supports, which is very expensive so that it dominates the cost of investment. As an overview, the wood support price is IDR 50 thousand, and if the average plant population is 1500 per ha, the investment needs of IDR 75 million per ha. Since agronomically, the supports are not directly related to productivity, replacing it with much cheaper live supports is highly recommended.

Most of the maintenance activities are conducted manually or labor-intensive; consequently, weeding activities are more costly than mechanical or chemical ones. However, productivity is higher because almost all plants are paid attention to individually. This is the key to pepper cultivation in Eastern Luwu, the total cost is higher, but the average cost is lower. Hence it is a higher possibility to achieve higher profit.

Table 4. Assessment of sustainability from unit expenses

| Description                                | thousand IDR | ton |
|--------------------------------------------|--------------|-----|
| Investment (3 years)                       | 153,000      |     |
| Accumulated depreciation (7 years)        | 137,700      |     |
| Annual depreciation expenses               | 19,671       |     |
| Annual operational expenses                | 28,000       |     |
| Annual expenses                            | 47,671       |     |
| A minimum price (per ton)                 | 40,000       |     |
| The expected minimum annual yield          | -            | 1.19|
| Unit expenses ton\(^1\) for 1.4 ton ha\(^1\) yield | 34,050       |

The selling price at the farmer level depends on international market prices. This condition results in an uncertain profitability. Given that this condition has not been resolved until now, then the applicable strategy is to use the appropriate technology to increase productivity so that the average cost can be lower than the lowest pepper price. According to farmers’ experience, the lowest price of white pepper was IDR 40,000 thousand ton\(^1\), so based on the estimated expenses, the minimum annual yield is 1.19 ton ha\(^1\), it is lower than the real farmers' achievement of annual yield (1.4 tons ha\(^1\)) (Table 4). From an economic perspective, pepper sustainability is relatively secure.

5. Conclusions.

The pepper smallholder outstanding cultivation practices in East Luwu that can threaten sustainability from environmental and social perspectives are clean land clearing, monoculture planting pattern, utilization of wood supports, clean weeding, and processing. From an economic perspective, most cultivation practices are sustained because the higher cost incurred is offset by higher productivity.

Strategies to develop sustainable cultivation practices are implementing more appropriate technologies such as minimum tillage application, multispecies planting of cover crops, the use of live tree supports, and installation of waste treatment units from product processing.

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