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Research article

Challenges in the development of the cocoa and chocolate industry in Indonesia: A case study in Madiun, East Java

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Abstract: The development of the cocoa agroindustry in Indonesia is of considerable importance to respond the global demand for high quality cocoa beans and cocoa-derived products. This study analyzes the issues concerning the cocoa production in Indonesia, including cocoa productivity, post-harvest treatments, and smallholder farmer profitability, in order to confirm the theories regarding cocoa farming previously published in many works as well as to offer insights into challenges for future cocoa farming and cocoa downstream industry development in Indonesia. A simple random sampling method was used to select a total of 25 cocoa farmers from the five regions in Madiun, East Java. The selected farmers were interviewed using a semi-structured questionnaire consisting of 39 questions regarding demographic and farm characteristics, farm management and postharvest practices, and farm training and social capital. The results indicated that approximately 40% of farmers are 60 years old and over. Besides, most of the cocoa farmers (76%) have not received any proper education or have attended to primary school only. Furthermore, according to the data, the cocoa productivity is inversely correlated with the farm size. Finally, almost half of the farmers in Madiun sell their cocoa beans as non-fermented. From this study, it was clear that in order to improve the quality of cocoa beans, farmers should be encouraged to improve agricultural practices and postharvest processes. This research gives empirical evidence of some constraints for high-quality cocoa production in Indonesia.

Keywords: chocolate; cocoa production; cocoa farming; agro-industrial challenges; sustainable agriculture; Indonesia

1. Introduction

Chocolate has been acknowledged as the most popular confectionery products in the world [1]. In this instance, Switzerland was the country with the highest chocolate consumption per capita followed by Austria, Germany and Ireland, with an average consumption of 7.9 to 8.8 kg per capita, in 2017 [2]. The popularity of chocolate might be due to the awareness of people to the fact that cocoa (*Theobroma cacao* L.), the main ingredient of chocolate, contains bioactive compounds potentially providing beneficial health effects [3]. In more detail, chocolate is rich in antioxidants such as flavonoids and flavanols, responsible for destroying free radicals in the body. Free radicals are unstable molecules that can cause damage to DNA and other cell components within the body, accelerating aging and possibly contributing to heart disease, cancer or other diseases [4–7]. Currently, many food scientists and industries even consistently develop a new type of cocoa-derived food and beverage products [8–15]. This condition results in a high demand of cocoa beans from major worldwide cocoa producing countries such as Ivory Coast, Ghana, Nigeria, Cameroon, and Indonesia [16].

Cocoa is in fact originated from Ancient Central America and was brought to Indonesia by the Dutch before 1900. Nowadays, Indonesia has approximately 1.5 million hectares of cocoa plantations mainly located in Sulawesi, North Sumatra, Papua, and Java [17]. Approximately 95% of cocoa plantations in this country belong to smallholder farmers, and thus cocoa production is the main income source for over 1,400,000 farmers and their families. East Java Province is one the most promising regions to be developed as cocoa agroindustry center, in addition to Sulawesi, Sumatera, and Papua as the main central production of cocoa in Indonesia. This is because East Java has the largest cocoa farming area with small-holder farmers, and also the highest cocoa producing region in Java [18]. The production of cocoa in Indonesia demonstrates several advantages such as low cost, high production capacity, efficient infrastructure for shipping and transporting the beans in open trading ways [19]. Most of the Indonesian cocoa production is exported to Malaysia, the USA, and Singapore as raw beans [20].

Regarding the current situation of cocoa production, the Indonesian government has committed to develop cocoa agroindustry. In this context, the Ministry of Industry has spent more than IDR 109.000.000.000 (equal to US $ 7.340.000) to build cocoa downstream industries in Sulawesi and Java during 2014–2019 [21]. Not with standing, according to the National Bureau of Statistics of Indonesia [17], the Indonesian cocoa production has gradually decreased about 29% from around 410.000 tons in 2012/2013 to 290.000 tons in 2018/2019 making this country downgraded from the 3rd to the 5th highest cocoa producing country in the world. The decrease of cocoa productivity might be attributed to poor farm management practices, aging cocoa trees and inadequate use of fertilizers [22]. Some other factors, such as incidence of pests and diseases as well as climate change, could also affect cocoa productivity [23–24]. In any case, it is crucial to overcome these problems and also to identify the most effective and sustainable ways to strengthen cocoa productivity and supply high-quality cocoa beans to the world. It has been widely acknowledged that sustainable production of agricultural products, including cocoa, plays a pivotal role in the society as it provides sufficient raw material that meets the market requirements without compromising the environment and/or the natural resources, and strengthening the agriculture economy by both, increasing the profitable farm income and enhancing the life quality of farmers and communities [25–26].

The district of Kare located in Madiun Regency, East Java Province, is an important agricultural center producing cocoa beans. Kare has a population of 32,014 people and covers an area of 19,085 hectares. In

Kare, most of people are smallholder farmers and use their home yards as cocoa plantations [27]. According to Hatani and his co-worker [28], the development of cocoa agroindustry with competitive advantages can be approached by market orientation, supply chain flexibility, and strategic location. They reported that market orientation, selecting strategic location and variable control of institutional support had significant effect towards the increasing of competitive advantage, but could not prove that supply chain flexibility gave significant contribution towards the increasing of competitive advantage in cocoa agroindustry. The uncertainty of supplier (cacao farmers) was found to be the main cause of it. Therefore, the involvement of smallholder farmers is needed to get a more serious concern, instead of other factors affecting cocoa productivity. Moreover, farmers should be encouraged to sustainably intensify farm management by adopting good agricultural practices that may enhance productivity, improve livelihoods by raising profitability as well as protecting environment for ensuring sustainability [29]. Kare, therefore, is an interesting and a suitable sample for investigating challenges in the development of cocoa and chocolate industry in Indonesia. Thus, the main objective of this research was to analyze the cocoa farming issues at farm-level through the perception of farming and postharvest practices in Madiun, East Java. This is important to validate the theories regarding cocoa farming that have been previously published in many works as well as identify the most effective and sustainable ways to strengthen cocoa productivity in Indonesia. Moreover, this work is significant to provide insights into challenges for the development of the downstream cocoa industry, particularly in Madiun. The dataset of demographic characteristics, farm characteristics, farm management practices, post-harvest practices as well as the farmers training and social capital are highly required to get a better insight of the cocoa farming conditions.

2. Materials and methods

2.1. Sampling and data collection

The study was conducted in April 2019. A simple random sampling technique was used to select a representative sample of cocoa farmers in Madiun, East Java. Five cocoa farmers were randomly selected from each one of the sub-districts (Karangagung, Randualas, Dawung, Slaji and Kajen). Face-to-face interviews with the selected farmers were conducted using a semi structured questionnaire following the study of Kongor et al. [29]. The questionnaire covered five issues including demographic characteristics, farm characteristics, farm management practices, post-harvest practices and farmers training and social capital. Demographic characteristics of the farmers included age, gender, educational level, marital status, number of children they have, willingness of children to become farmers, support of parents with the farmers children's desire to become or not farmers, and years of experience in cocoa cultivation. Farm characteristics included size of cocoa farms (in hectares), age of the farms, quantity (kg) of dried cocoa beans obtained, and opinion about the fertility of the soil. Farm management practices included the type of farming system, type of plants used as shade trees, major diseases and pests that attack cocoa trees, way of weed control, spraying of diseases and pests, fertilizer application, way of pruning, and mistletoe removal. Post-harvest practices included times number of cocoa pods harvesting, conditions of pods storage, and cacao beans fermentation and drying. Farmers training and social capital included kind of training received in the last 12 months, kind of training desired to receive from buyers, way of selling the cocoa beans, typical buyer of cocoa beans, amount

of money gotten for 1 kg of fermented or non-fermented cocoa beans, agreement of selling fermented and dried cocoa beans to buyers, and desired price for 1 kg of fermented and dried cocoa beans.

2.2. Data analysis

Simple calculation by dividing total quantity of dried fermented beans by total farm size was conducted to estimate the productivity. To analyze the socio-economic characteristics of the farmers, the descriptive statistics was used. The data obtained from the descriptive research was then used for further analysis to draw a better description as well as a conclusion [30].

3. Results

3.1. Demographic characteristics

The results of the investigation on the demographic characteristics of cocoa farmers are presented in Table 1.

Table 1. Demographic characteristics in percent (%) of cocoa farmers interviewed in Madiun.

Background characteristics	Region / Options	Karangagung	Randualas	Dawung	Slaji	Kajen	Average (5 regions)
		n = 5	n = 5	n = 5	n = 5	n = 5	n = 25
Gender	Male	100	100	80	100	100	96
	Female	-	-	20	-	-	4
Age	21–40	-	-	-	40	-	8
	41–60	60	40	60	40	60	52
	≥60	40	60	40	20	40	40
Education level	No education	20	-	-	-	-	4
	Primary level	80	100	60	40	80	72
	Secondary level	-	-	40	40	20	20
	Tertiary level	-	-	-	20	-	4
Marital status	Married	100	100	100	100	100	100
No. of children	0–1	-	-	-	20	-	4
	2–3	80	100	80	80	80	84
	>3	20	-	20	-	20	12
Do the children want to be farmers?	Yes	20	60	60	40	20	40
	No	80	40	40	60	80	60
Farming experience time (years)	1–10	20	20	40	-	-	12
	11–20	-	20	60	40	60	32
	21–30	60	20	-	40	20	28
	>30	20	40	-	20	20	28

The majority of cocoa farmers were male (96%). There was only one female farmer in the district of Dawung (4%). It was identified that 52% of the cocoa farmers are between 41–60 years old, 40%

of farmers are older than 60 years old, and only 8 % of farmers are younger than 40 years old. With respect to the educational level, most of the farmers (96%) have education at different level and only 4% of them have not received any education. The majority of the farmers (72%) have received primary education, 20% of the farmers have attended to secondary school and 4% of the farmers have a tertiary education level.

About marital status of farmers, 100% of them are married. Most of the farmers (84%) have 2 or 3 children. Only 12% of the farmers have 4 children and 4% of them have 1 child. According the farmers, most of their children (60%) are not interested about becoming farmers in the future as the children want to execute another profession, mainly in the big cities. With respect to the farming experience, the majority of the farmers (32%) have between 11–20 years of cocoa farming experience; only 12% have between 1–10 years of experience; 28% of farmers have 21–30 years of experience; equally, 28% of farmers have more than 30 years of farming experience. The relatively long farming experience should enhance knowledge of cocoa production and postharvest processes. Finally, 68% of people interviewed execute the role of farming as main activity, and hence farming is the main income source. Nevertheless, it was identified that the income is the result of several products such as cacao, coffee, clove, banana, mango, teak, avocado and orange. The farmers do not focus in one product only because the production together with the price varies during the year. Consequently, they need to have various products available to generate profit.

3.2. Farm characteristics

The overview of farm characteristics of cocoa farmers interviewed in Madiun are presented in Table 2. The majority of cocoa farmers (56%) own one farm. However, 40% of them own 2 and 4% owns 3. The farmers grow two varieties of cocoa: Forastero and Criollo. All of the farmers from Dawung assessed that their farms are 1–10 years old, representing 44% of the total farmers. Another 44% of the farmers indicated that their farms are 11–20 years old. Few farmers have farms between 21–30 years old and, only 4% of the farmers indicated that their farms are older than 30 years. The average farms age and size are presented in Figure 1.

Figure 1 also shows the productivity of the cocoa farms. With respect to the quantity of dried cocoa beans, most of the farmers (60%) indicated that they obtain 50–200 kg/year; 32% of them get 210–300 kg/year; 4% of the farmers obtain 310–400 kg/year and, also 4% of them achieve more than 400 kg/year. The level of dried cocoa beans productivity was in the order of Dawung > Slaji > Kaje > Randualas > Karangagung. All of the farms from Dawung are 1–10 years old. Karangagung on the other hand, has farms which trees vary from one to more than 30 years old.

Table 2. Farm characteristics in percent (%) of cocoa farmers interviewed in Madiun.

Background characteristics	Region / Options	Karangagung	Randualas	Dawung	Slaji	Kajen	Average (5 regions)
		n = 5	n = 5	n = 5	n = 5	n = 5	n = 25
No. of cocoa farms	1	60	40	60	80	40	56
	2	20	60	40	20	60	40
	3	20	-	-	-	-	4
Age of the farms	1–10	40	20	100	20	40	44
	11–20	40	60	-	60	60	44
	21–30	-	20	-	20	-	8
	>30	20	-	-	-	-	4
Quantity of dried cocoa beans (kg/year)	50–200	100	40	80	40	40	60
	210–300	-	60	20	40	40	32
	310–400	-	-	-	20	-	4
	>400	-	-	-	-	20	4
Productivity of cocoa beans (kg/ha/year)	100–250	80	40	-	-	-	24
	260–400	20	-	20	-	40	16
	410–550	-	20	20	80	20	28
	>550	-	40	60	20	40	32

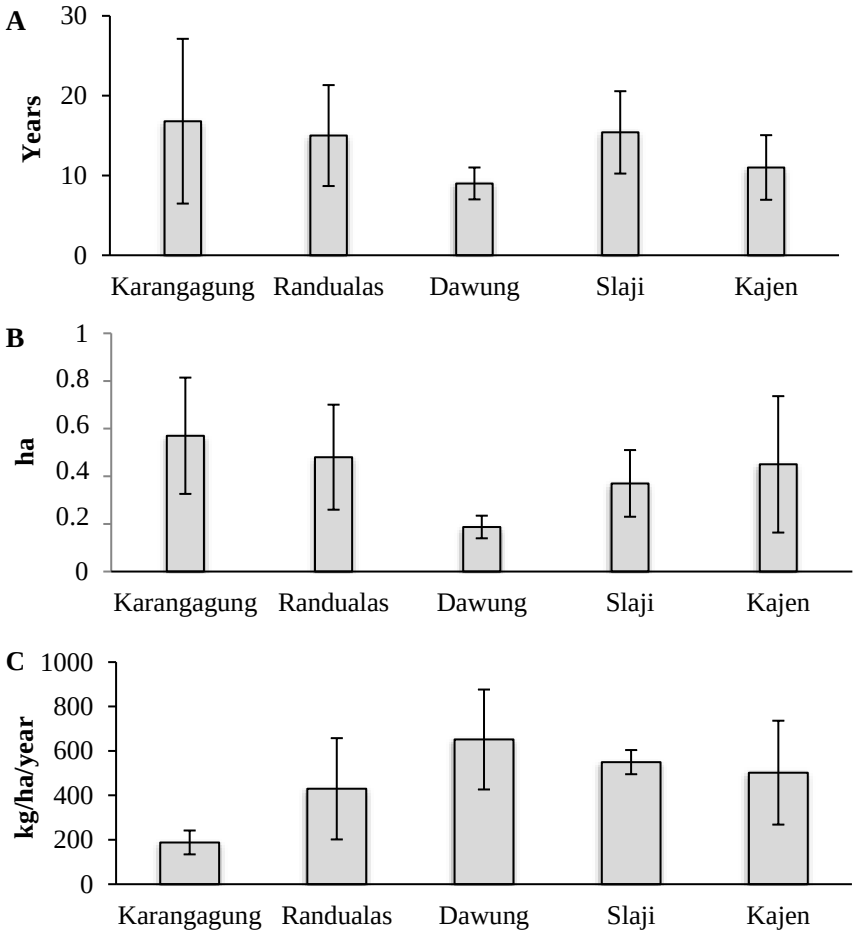

Figure 1. Average farms age (A) size (B) and productivity (C) in five cocoa growing regions of Madiun.

3.3. Farm management practices

The summary of farm management practices of cocoa farmers interviewed in Madiun are presented in Table 3. All of the farmers ensured that the type of farming system was mixed cropping. Most of the farmers (84%) have more than two types of crops mainly cloves, mango, banana, durian, coffee, orange and lemon. The rest of the farmers (16%) mix their cacao crops with cloves only. Besides, 72% of cocoa farmers practiced intercropped farming system. The rest of them (28%) dispose of specific areas for each of the crops planted. The crop that 68% of the farmers use as shade trees for cocoa is clove; 12% of the farmers use mango, and the remaining 20% of people use banana, teak or avocado.

Table 3. Farm management practices in percent (%) of cocoa farmers interviewed in Madiun.

Characteristics	Region / Options	Karang agung	Randualas	Dawung	Slaji	Kajen	Average (5 regions)
		n = 5	n = 5	n = 5	n = 5	n = 5	n = 25
Type of weed control	None	-	20	20	-	20	12
	Weeding	60	60	40	80	40	56
	Herbicides	40	20	40	20	40	32
Weed control (times/year)	0	-	20	20	-	20	12
	12	-	60	20	40	40	32
	24	20	20	40	40	-	24
	≥ 36	80	-	20	20	40	32
Major diseases	Black pods	80	80	80	40	40	64
	Moniliasis	20	20	20	-	-	12
	Black pods and Monilisis	-	-	-	60	60	24
Spraying of diseases	Spray machine	40	60	60	80	100	72
	Cutting diseased part	60	40	40	20	-	28
Major pests	Capsides	-	60	40	60	100	52
	Fruit flies	40	-	60	40	-	28
	Ants, flies, squirrels	60	40	-	-	-	20
Spraying of pests	Spray machine	80	80	80	100	100	88
	Pest trap	20	20	20	-	-	12
Fertilizer application	Yes	60	80	80	100	100	84
	No	40	20	20	-	-	16
Fertilizer application (times/year)	0	40	20	20	-	-	16
	1	20	20	60	40	-	28
	2	-	60	20	20	-	20
	≥ 3	40	-	-	40	100	36
Pruning	Use of cutlass	20	80	60	80	80	64
	Use of sickle	80	20	40	20	20	36
Mistletoe removal	Yes	40	40	40	60	60	48
	No	60	60	60	40	40	52

Regarding the weed control, 12% of farmers do not apply any measure, 56% of the farmers perform weeding and 32% of them use herbicides. Moreover, 32% of the farmers apply weed control

measurements 12 times/year, 24% of the farmers 24 times/year and 32% of them 36 or more times/year. A summary of the weed control application of the different region is presented in Figure 2. It can be appreciated that Karangagung, the region with the biggest farms, apply weed control more times per year than the rest of the regions. However, the productivity is the lowest. With respect to the major diseases, 64% of the farmers stated that black pods are the one that attack the most to their cocoa crops, 12% of the farmers indicated moniliasis as the most severe disease and 24% of the farmers stated that both black pods and moniliasis are the major diseases in their cocoa crops.

Most of the farmers (72%) use spray machine to counteract the diseases of their crops. However, 28% of the farmers prefer not to spend money and cut the diseased part of the plant. Regarding the major pests, 52% of the cocoa farmers stated that capsids are the ones that attack the most to their cocoa crops, 28% of the farmers indicated fruit flies and 20% of the farmers agreed that the major pests are ants, white flies and squirrels. The majority of the farmers (88%) use spraying machines with insecticides to control pests. Nonetheless, 12% of them use pest traps (Petrogenol) to counteract them. With respect to the pruning, most of the farmers (64%) rather using cutlass and 36% of them prefer the use sickle. Finally, 48% of the farmers remove mistletoes from the cocoa plants but 52% of them do not remove mistletoes.

A great number of farmers (84%) specified that they apply fertilizers to the crops. Only 16% of them do not apply any type of fertilizer. The majority of the farmers (36%) that apply fertilizer to their crops do it three times/year, 20% of the farmers do it twice a year and 28% of them do it just once a year. The fertilizers mostly used by the farmers are compost, EM4 and TSP posca. Dawung is the most productive region despite the fact that this region applies fertilizers fewest times/year. All the farmers from Dawung fertilize their cocoa crops two or less times/year. In the region of Karangagung, on the other hand, 40% of the farmers fertilize their crops three or more times/year. A summary of the fertilizer application of the different region is presented in Figure 2.

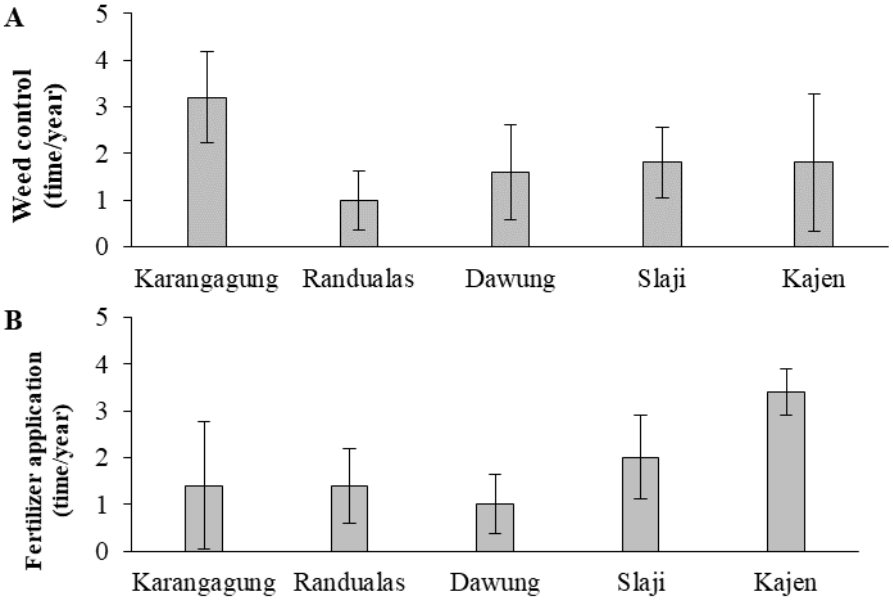

Figure 2. Weed control (A) and fertilizer (B) applications in five cocoa growing regions of Madiun.

3.4. Postharvest practices

The results of postharvest practices assessment to the cocoa farmers in Madiun are presented in Table 4.

Table 4. Postharvest practices in percent (%) of cocoa farmers interviewed in Madiun.

Characteristics	Region / Options	Karangagung	Randualas	Dawung	Slaji	Kajen	Average (5 regions)
		n = 5	n = 5	n = 5	n = 5	n = 5	n = 25
Harvesting times/week	< 1	20	-	-	20	20	12
	1	40	100	100	60	80	80
	2	40	-	-	20	-	8
Fermentation of cocoa beans	Yes	60	20	60	80	60	56
	No	40	80	40	20	40	44
Drying of cocoa beans	Yes	100	100	100	100	100	100
	No	-	-	-	-	-	-

The majority of the farmers (80%) harvest the cocoa pods once a week, 12% of them harvest once every two weeks and 8% of the farmers harvest twice every week. It is important to mention that farmers do not keep count of the quantity of cocoa pods harvested. They only have an idea of the amount of dried beans produced at the end of the week; which is the same quantity used to calculate the productivity presented in Table 2.

Regarding postharvest practices, there are at least three important aspects that should be taken into account for evaluations. Firstly, none of the cocoa farmers store the pods prior opening. The farmers harvest all of the pods and proceed to open them immediately to obtain the beans. Secondly, only 56% of the farmers ferment the cocoa beans. The remaining 44% of the farmers proceed to the drying of the beans after the pods opening. Half of the farmers that ferment the beans use plastic containers for the process, 21.4% of them use baskets, 14.3% of them prefer heap and another 14.3% use sacks. Besides, 71.4% of the farmers that ferment the beans do it for two or three days, while the rest (28.6%) do the fermentation for four or five days. Finally, only 42.8% of cocoa farmers turn or mix the beans for aeration during fermentation and the remaining 57.2% do not move the beans during the process. Thirdly, all of the farmers interviewed dried the cocoa beans by sun drying. Most of the farmers (80%) using bamboo mats, whereas the rest of the farmers (20%) dry the beans in sacks. Moreover, the majority of the farmers (72%) dry the beans during two or three days and the remaining 28% of farmers dry the beans for four or five days.

3.5. Farmers training and social capital

Table 5 shows postharvest practices conducted by the cocoa farmers interviewed in Madiun. Most of the farmers (80%) have not received any kind of training within the last 12 months. Only 20% of the farmers have received training, 80% of them received training from the government and the remaining 20% from the buying company. All of the farmers that received training, learnt about farming practices and health and safety. With respect to the kind of training that the farmers would like to receive from other parties, the results are presented in Figure 3. Most of the farmers (72%) are

interested about farming practices and postharvest treatment. Meanwhile, the rest of them are interested about cocoa beans processing and entrepreneurship.

Table 5. Farmers training and social capital in percent (%) of cocoa farmers interviewed in Madiun.

Characteristics	Region / Options	Karangagung	Randualas	Dawung	Slaji	Kajen	Average (5 regions)
		n = 5	n = 5	n = 5	n = 5	n = 5	n = 25
Farm training	Yes	-	-	-	60	40	20
	No	100	100	100	40	60	80
Selling of cocoa beans	Fermented	60	20	60	60	60	52
	Non-fermented	40	80	40	40	40	48
Buyer of cocoa beans	Collector	40	100	80	100	80	80
	Market seller	60	-	-	-	-	12
	Government	-	-	20	-	20	8

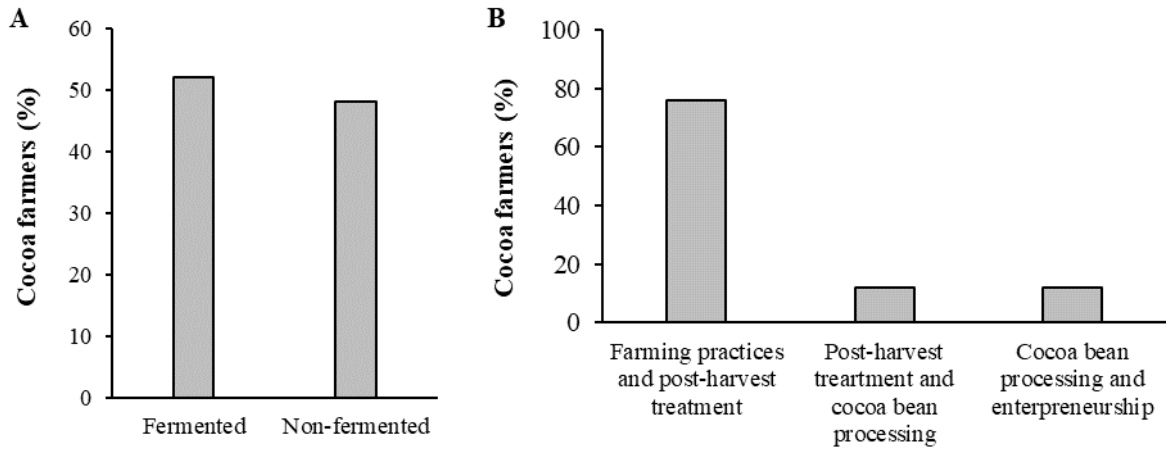

Figure 3. Way of cocoa beans selling by cocoa farmers interviewed in Madiun (A) and kind of training are willing to receive (B).

Figure 3 also shows the way of cocoa beans selling by cocoa farmers in Madiun. It was identified that 52% of the farmers sell fermented cocoa beans while 48% of them sell the beans in non-fermented way. The average price of fermented beans is IDR 22.400 (equal to USD 1.61) and the average price of non-fermented beans is IDR 22.000 (equal to USD 1.58). The majority of farmers (80%) sell the dried beans to the collector; 12% of them sell the dried cacao beans to the market seller and 8% of the farmers sell the beans to the government. Besides, when the farmers knew about the interest of another company about buying fermented and dried cocoa beans, 100% of them agreed in selling the product for a higher price which in average is IDR 30.840 (equal to USD 2.22).

4. Discussion

Sustainable production of cocoa plays a significant role in the sustainability of chocolate industry. Particularly in Indonesia, information of cocoa production is very crucial as the basis of the development of cocoa-based industry that is being directed by the government. To give insight in the cocoa production in Indonesia, the dataset of demographic characteristics, farm characteristics, farm

management practices, post-harvest practices and the farmers training and social capital is important. Thus, a study about cocoa farming and production in Madiun was then conducted. This study is also important to confirm the theories regarding constraints in global cocoa farming previously published in many works by different research groups.

In this research, it was found that the majority of cocoa farmers were male despite the fact that women may be significant players. This tendency might be because agricultural work performed by women is seen as secondary to their domestic responsibilities [31]. Agreeing to the finding of Kongor et al. [29], cocoa farming requires physical strength giving a reason why cocoa farming is dominated by male. Among the farmers, as shown in the results, less than 10% of interviewed farmers are below 40 years old. It might affect the cacao productivity as the age of farmers is highly correlated to physical strength.

In addition to the age, education can contribute to the productivity of cocoa farm. The region with least education level is Karangagung, which at the same time, is the least productive region. Education helps farmers to better understand the Good Agricultural Practices on cocoa farming as well as to implement innovative processes and technologies in the farms. Moreover, education is the key component to make agriculture more appealing to children. In order to make people realize that mostly smallholder farmers are the ones who feed the world, important actions have to be taken. For instance, it is necessary to emphasize the importance of agriculture in schools, constantly train farmers, improve public policies, create role models that show how success agriculture looks like and better support farmers regarding access to inputs and markets to sell their products at a fair price. Furthermore, it is necessary to highlight the importance of agriculture through training and educational programs so the farmer's income is fair and allows them to apply good agricultural practices.

Aside from the current situation of ages and education level of the farmers, the future cocoa farming in Madiun must get more attention from the government. As such, most of the farmer's children are not interested about becoming farmers in the future as they want to have another profession in the big cities. In fact, the parents respect and support the decisions of their children. The parents are aware that the farming work is hard and, at the same time not well recognized nor well paid. The cocoa productivity as well as the amount of money that farmers earn from selling dried cocoa beans is not enough for covering their expenses. Consequently, instead of exclusively selling cocoa beans, farmers prefer to plant different types of crops and sell as much products as they can in order to have better income. Thus, despite the fact that they own lands, the parents support their children with the decision of performing another better paid occupation. If measurements are not taken, in the future years, fewer smallholder farmers will be working on their lands and the cocoa production will be less and less. Probably most of them will sell their lands to environmental destructive agribusiness companies which only care about revenues. Young people aspire to study in order to be part of formal employment sector and have modern urban lifestyles. However, it is a fact that education does not necessarily lead to employment.

The present situation of cocoa productivity in Madiun appears to be highly correlated with the ages of the trees and the size of the farm. According to Binam et al. [32], the production of cocoa trees increases after four years of planting and its yield increases annually until about 18 years of age, afterwards it starts to decrease. It was shown in this study that all of the farms in Dawung are 1 to 10 years old. Besides, in this region, the average size of the farms is the smallest (0.2 ha) which makes maintenance and care of trees and soil easier than in bigger farms from the other regions. Therefore, the cocoa trees of Dawung are the most productive. Karangagung, on the other hand, has farms which

trees vary from one to more than 30 years old. Hence, the production of the old trees has begun its decline. Besides, the big average area of the farms (0.6 ha) makes difficult the maintenance and care of soil and trees which also affects the cocoa productivity. These results are consistent with the ones from Kongor et al. [29] who found that cocoa productivity is inversely correlated with the size of the farm.

The cocoa productivity in Madiun is influenced by the presence of diseases, such as black pod and moniliasis. Black pod, caused by *Phytophthora palmivora* or *Phytophthora megakarya* is a fungal disease of cocoa characterized by browning, blackening and rotting pods and beans [33]. Moniliasis is also a fungal disease caused by *Moniliophthora roreri* which is responsible for dark spots on the surface of pods followed by the appearance of "white powder" or fungus conidia that rot the pods [34]. Both diseases can cause serious losses and are economically important. The high incidence of black pod and moniliasis diseases in Madiun might be because the average rainfall is 1912 mm annually and the average temperature is 27 ℃. The high humidity and temperature favor fungal growth. Another factor affecting cocoa productivity is the incidence of pests. The major pests reported in this study are capsids, ants, white flies and squirrels. All of these pests are responsible for damaging the surface of cocoa stems, branches, or pods, sucking the sap of the tree or feeding the pods and causing necrotic lesions. As the high incidence of diseases and pests affects the productivity of cocoa trees, it is necessary to manage adequately these problems by increasing the control times per year. As found in this study, to counteract the diseases of their crops, most of the farmers use spray machine. The spraying machine is also used with insecticides to control pests.

To help improving the productivity, the cocoa farmers (more than 80%) use fertilizers. Fertilizers are essential to provide adequate nutrients for crop growth and assure a successful harvest. However, according to Dubos et al. [35], prolonged fertilizer application has an impact on the structure and composition of the soil. For instance, ammonia-based fertilizers (nitrate, phosphate, sulphate, or chloride) drop the pH of the soil in a short time span of 10 years by almost two pH units. Excessive acidity or alkalinity can affect the cocoa tree growth and production. International Cocoa Organization [36] recommended an optimum pH for cocoa growth which is in the range of 5.0 to 7.5. Another long-term risk of using fertilizers is the accumulation of contaminant trace elements into the soil. Elements such as As, Cd, and Pb may threat the inherent soil quality and harm human health [37]. Fertilizer requirements of cocoa depends on different factors such as nutrition quality of the soil, age of the trees, peak cropping period, competition from weeds and rainfall pattern. It is often recommended that fertilizer application should be done twice a year: April and September [38].

Nevertheless, it was found in this study that the fertilizer has less effect on cocoa productivity than the age of the cocoa tree. As such, the fertilizer application by farmers in Slaji and Kajen is more frequently than those in Dawung. As Dawung has the smallest farms (0.2 ha) and the youngest trees (1 to 10 years old), this region has the highest cocoa productivity (651.5 kg dried cocoa beans/ha/year). In the region of Karangagung, 40% of the farmers fertilize their crops three or more times/year. Because of the old age of some of the trees (> 30 years) and the multiple fertilizer application, the original composition and pH of the soil have been altered and, the cocoa productivity is lower than in the other regions (188 kg dried cocoa beans/ha/year). Furthermore, the old trees had lost their natural defense mechanisms against pathogens and had started their senescence period, which affect seriously their productivity [39]. It would be proper to clear away old cocoa trees and re-plant [40].

It would be interesting to perform statistical analyses to investigate deeper the correlation between productivity and farm age, farm size, weed control as well as fertilizer application. However, as in this

region the cocoa farming is done in the farmers' home yard, the number of the cocoa tree per hectare of yard is not similar, and thus the statistical analysis is not possible to perform. Nevertheless, the descriptive analysis can already provide insight to draw a conclusion about the condition of cocoa farming in Madiun.

The quality of cocoa beans is not only affected by farming practices, but also strongly influenced by the post-harvest treatment. Maintaining the quality of cocoa beans is highly important as at the end, it determines the quality of chocolate. According to Afoakwa [41], the ideal postharvest processes of cocoa beans include: (a) storage of the pods; (b) opening of the pods with a thick piece of wood; (c) fermentation of the cocoa beans for at least five days; and (d) drying of the cocoa beans to remove the moisture content.

Unfortunately, the postharvest treatments in Madiun have not met those ideal conditions. For instance, none of the cocoa farmers store the pods prior opening as they proceed to open them immediately to obtain the beans. According to Hinneh et al. [42], the storage of the cocoa pods leads to the reduction of nib acidification during subsequent fermentation, reduction of the acid note and an increase in cocoa flavor in the resulting raw cocoa. Consequently, the lack of pods storage will affect the quality of the cocoa beans.

Aside from the pod storage issue, it was also found that almost half of cocoa farmers interviewed in Madiun do not perform the fermentation processes. Fermentation is very pivotal for developing appropriate flavour precursors [42]. During the fermentation, microorganisms such as yeast and bacteria grow on the pulp surrounding the beans. Shortly, yeast converts the sugars in the pulp to ethanol. Afterwards, bacteria oxidize ethanol to acetic acid and then to carbon dioxide and water raising the temperature. Eventually, the acetic acid and high temperature kill the cocoa bean resulting in the breakage of cells. Hence, all of the released components mix, allowing complex chemical changes such as enzyme activity, oxidation and breakdown of proteins. The interaction of these metabolites together with the enzyme activity, oxidation, and brake down of proteins into amino acids, are the precursors for cocoa bean flavor [43]. Even though cocoa bean fermentation is a very important process, almost half of the farmers directly dry the beans after harvesting without doing fermentation. Consequently, the flavor of the resulting beans will have poor quality.

The main reasons why farmers prefer not doing fermentation are economic constraints such as immediately cash necessity and no price difference between fermented and non-fermented cocoa beans. The average price of fermented beans is IDR 22.400 and the average price of non-fermented beans is IDR 22.000 (USD 1 is about equal to IDR 13.900). There is no significant difference between the price of fermented and non-fermented beans. Moreover, the farmers also consider the fermentation duration that required at least 5 days. Those reasons make a great number of farmers prefer to avoid fermentation process. Hence, they directly dry the beans and sell them as fast as possible so they dispose immediately of cash.

Another issue related to post-harvest treatment is faced during the drying process. It was identified that all of the farmers dried the cocoa beans by sun drying, mostly layered using bamboo mats for two or three days. The aim of drying is to decrease the moisture content from about 60% to about 7.5%. With adequate sunshine the drying of the beans may take around one week. If the beans are dried too quickly, some of the chemical reactions started during fermentation are not allowed to complete resulting in acid beans with bitter flavor. Conversely, if the beans are dried too slowly, mold can grow and develop off-flavors [36]. Apparently, the drying time that most of the farmers apply is not enough

to decrease the moisture content to 7.5%. Consequently, the beans might be contaminated with mold and thus the cocoa beans can contain ochratoxin making the beans have low quality.

To increase the cocoa productivity and to improve the cocoa bean quality, educating the farmers through training programs is highly required. The soil characteristics together with the weather conditions in Madiun may be optimal for cocoa growth. Nevertheless, the limited farmers education and training restricts their good agricultural practices and cocoa productivity. There have been some cocoa farming training programs in Indonesia organized by different organizations such as Cocoa Life of Mondelez International, Rikolto Mars and Sustainable Cocoa Production Program (SCPP) [44–46]. However, as reported by the farmers, the programs have been developed in Sumatra and Sulawesi; none of them in Madiun. Briefly, it can be stated that there is a lack of cocoa training in Madiun. Based on the interview, most of farmers wanted to get trainings in cocoa farming practices and post-harvest treatments. Nevertheless, some of them seems interesting to improve their skills and knowledges in cocoa bean processing and entrepreneurship.

There are still a lot of constraints in the cocoa farming in Madiun, and therefore, the development of cocoa downstream industry in Indonesia becomes much more challenging. The quality of cocoa beans highly influences the quality of chocolate. To make chocolate from cocoa beans, there are several consecutive steps, including fermentation of the beans in order to develop the flavor precursor, roasting of the beans aiming to darken the color and develop the flavor characteristics of chocolate, and the process of breaking and winnowing aiming at removing the cocoa shell and obtaining the cocoa nib. To obtain the cocoa liquor, the process of grinding of the nib is required. The cocoa liquor is then mixed with the proper amounts of cocoa butter, sugar, milk and lecithin depending on the type of chocolate to prepare. After mixing, a refining process is needed to reduce the particle size and to get smooth texture, followed by conching process aiming to develop the chocolate flavors, to eliminate undesirable volatile compounds and to reduce the moisture content. Next, tempering is required to get desired crystal form and to obtain solid state chocolate, and then finally, molding is necessity to shape the chocolate [47].

The most important quality attribute of chocolate resides on the flavor. The flavor consists of the intensity of the cocoa flavor together with any ancillary notes and the absence of flavor defects. Fermentation is a vital stage of postharvest processes that can influence the quality of cocoa beans, in particular taste and aroma and color, and thus it has a vital role on the flavor profile of the chocolate [43]. As previously showed, a great number of farmers in Madiun do not perform fermentation of cocoa beans. To overcome this problem, it would be appropriate to educate and train farmers about good agricultural practices and post-harvest treatments. It is also important to improve government policies in order for the farmers to be paid fair and distinctive prices for good quality cocoa beans. In our view, this can be a significant starting point to develop downstream cocoa industry producing high quality chocolate in Indonesia.

The findings in this study confirm the conclusion drawn by Kongor et al. [29] that good farm management practices would significantly increase cocoa productivity, and thus ensure sustainable production of cocoa production. Furthermore, this research provides empirical evidence of some other constraints for high-quality cocoa production in Indonesia, including socio-economic aspects as above-discussed.

5. Conclusions

Cocoa production in Madiun are dominated by the smallholder farmers with an average farm size about 0.5 ha. Most of the farmers are older than 40 years with lack of formal education (most of the farmers have attended to primary school). An interesting finding in this research is that even though the fertilizer application times is lower than in other regions, Dawung was found to be the most productive cocoa region with 651.5 kg/ha/year. At the same time, this region has the youngest farmers and smallest farm size. Although most of the farmers have more than 10 years of farming experience, they still need to learn or improve their cocoa farming and postharvest skills. In fact, the cocoa productivity is still lower than the average cocoa productivity in the world and almost half of the farmers sell their cocoa beans as non-fermented. With an appropriate and regular training about cocoa farming, the use of integrated pest management, organic fertilizers, intercropping system and postharvest practices, the farmers can develop skills in good agricultural practices, counteract the pests and diseases issues, optimize their production capacity and increase productivity and profitability of the farms. Education and training are pivotal to produce high quality cocoa beans that is crucial as raw materials for the food industry. It is necessary to educate people, not only farmers but also collectors, market sellers and intermediates buyers, about the importance of high quality fermented dried cocoa beans so they can appreciate their value and pay a fair price. In this regard, government policies are required.

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Conflict of interest

The authors declare that they have no conflict of interest.

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