Farming Systems and GAP Adoption in JASS Coffee in Tlahab, Temanggung Regency, Indonesia

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ABSTRACT

Farming systems provide information about the complexity of agriculture at the household level in a region. In Temanggung, Indonesia, the Java Arabica Sindoro-Sumbing (JASS) coffee intercropped with tobacco and vegetables provides an interesting interaction study. Despite its potential, no in-depth research has been conducted on farming systems and the level of good agricultural practices (GAP) adoption in JASS plantations. This study sought to analyze farming systems and determine the level of GAP adoption by the JASS coffee farmers in Tlahab, Temanggung, Central Java Province. One hundred fifty-eight purposively sampled farmers were interviewed in depth. The study employed agrarian system diagnosis as tool for analyzing farming systems, and calculated GAP adoption using the chi-square test. Before 1999, the simple farming system consisted of planting tobacco and red beans during the dry season, switching to corn during the rainy season, and keeping livestock for emergency savings and manure. However, erosion was a major problem because few wood trees existed. Farmers grew JASS coffee in large quantities and positioned it as a conservation plant and as a new income source. After 2000, they grew JASS coffee alongside tobacco and red beans during the dry season, followed by more diverse cropping during the rainy season. The study classified the JASS coffee farmers as specialist, rainforest, and diversified coffee farmers. Plant spacing and intercropping had more than 75 percent adoption rate, water and soil conservation, along with growing shade trees, had 30 to 50 percent adoption, while fertilizing and pruning had less than 25 percent. Specialist coffee farmers dominated the practice of GAP cultivation and had higher yield and income from coffee cherries than two other types of farmers.

Keywords: coffee, farming system, GAP, JASS
JEL codes: Q15

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INTRODUCTION

Agriculture is one of the crucial sectors in Indonesia, with coffee as its top export to developed countries (Pratama, Sripruetkiat, and Fournier 2019; Ram 2017). Coffee is thus an important commodity produced at Temanggung Regency. While agriculture is generally known as a complex area of study, analyzing farming systems could answer questions about the diversity of agriculture and their relationship with each other in a region. Agrarian system diagnosis can identify and characterize the main challenges of small agricultural and rural areas. This systemic approach combines various disciplines, such as agronomy, sociology, and economics. This study assumes that farmers rationally choose farming systems based on environmental, economic, physical, political, and sociocultural factors.

Temanggung Regency is in the highlands, surrounded by volcanoes, and agriculture is its primary income source. Coffee, tobacco, and vegetables are economic drivers for smallholders in this area. These are crucial to their wellbeing and have driven rural development. More specifically, one of the leading commodities of Temanggung Regency is Java Arabica Sindoro-Sumbing (JASS). JASS coffee has obtained a geographical indication (GI) certificate[1] because it has unique characteristics such as a mildly bitter taste and moderate acidity with lemon, floral, spicy, honeyed, flowery, chocolaty, and caramel aromas (Yusuf and Hadi 2019). JASS coffee is grown intercropped with tobacco and food crops, especially in Tlahab. Hence, studying the dynamics of farming systems using agrarian system analysis and diagnosis is relevant in this area.

JASS coffee was produced at around 962.98 t in Temanggung Regency, accounting for 41 percent of total arabica coffee production in Central Java Province. However, JASS coffee productivity has remained low, around 530 kg/ha, compared with Indonesia's arabica coffee productivity of around 811 kg/ha (BPS 2021). In addition, poor agricultural practices for JASS coffee and other surrounding crops could lead to environmental issues such as soil erosion, water scarcity, infertile soil, pest resistance, and new plant diseases. Climate change is another problem with significant implications for agriculture and the environment (Kusumasari 2016). Heavy rain occurs during summer, which is the JASS coffee flowering season. High rainfall causes flowers to fall before they are fertilized. From 2021 until 2022, coffee farmers in Tlahab experienced a dramatic drop in coffee production.

Good agricultural practices (GAP) are believed to overcome these problems. The increasing adoption rate of GAP is expected to increase productivity (Mahfud, Nurbanah, and dan Ardiansyah 2010). Indonesia has set GAP standards for coffee since 2014, which are stated in regulation number 49/Permentan/OT.140/4/2014. GAP is also designed to assist coffee farmers in dealing with environmental problems and climate change by promoting sustainable practices. It includes nine points of coffee cultivation practices based on established standards. However, the adoption rate for each practice is unknown in Temanggung; hence this study.

The study sought to analyze farming systems and determine the level of GAP adoption among coffee farmers in Tlahab, Temanggung Regency. The study also contributes new literature in two ways. First, farming systems could provide the background to understand different farming practices. Second, the study determines the levels of GAP adoption and their performance on coffee yield. This would help provide more specific policy implications to increase the adoption of GAP practices. Moreover, it would inform how JASS coffee farmers can further increase productivity and household income, thereby strengthening rural livelihood.

1 A GI is a sign used on products that have a specific geographical origin and possess qualities or a reputation that are due to that origin (https://www.wipo.int/geo_indications).

METHODOLOGY

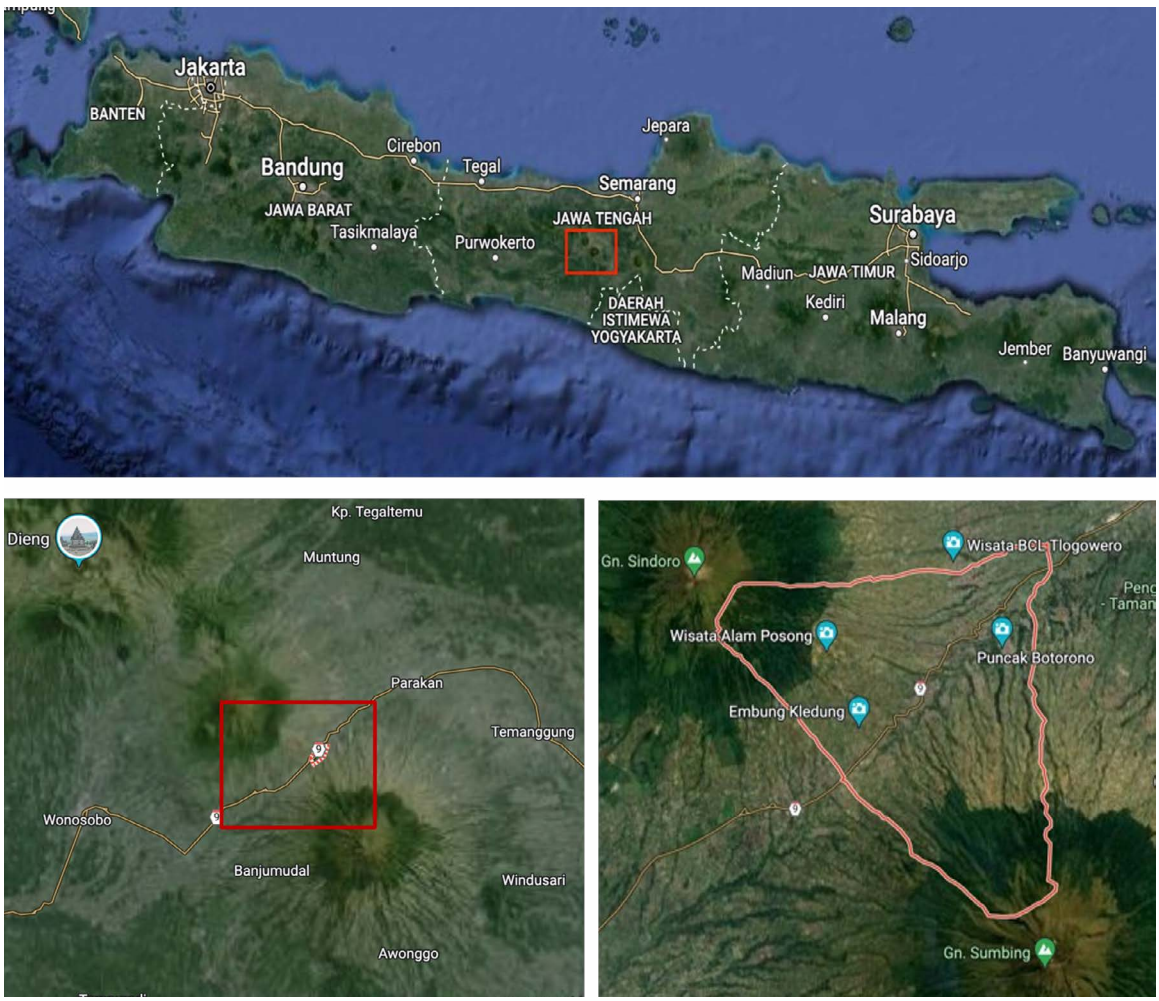
The Study Area

The study site was Tlahab, Subdistrict Kledung, Temanggung Regency. Tlahab served as the JASS coffee plantation's pilot area, with farmers growing JASS coffee with other crops. The study area is situated on the volcanic slopes between Mount Sindoro and Mount Sumbing, at an elevation of 1,339 meters above sea level (masl). It has an approximate 650 family heads of coffee farmers, farming being the dominant occupation.

Data Collection and Sampling

The study sample was determined using a sampling percentage table, allowing a population between 101 and 1,000 to be represented by at least 10 percent of the total population (Arikunto 2006). The minimum sample size was 65 coffee farmers. A total of 158 coffee farmers were sampled purposively. The questionnaires inquired about agroecology, history, socioeconomic characteristics, and whether farmers followed any of the nine practices mandated by the GAP guidelines in regulation number 49/Permentan/OT.140/4/2014.

Figure 1. Study area in Tlahab, Temanggung Regency, Central Java Province, Indonesia



Data Analysis

The study combined qualitative and quantitative approaches to analyzing data.

Farming systems analysis

The study analyzed the farming system using the procedure of agrarian system diagnosis (Ferraton and Touzard 2009). In summary, the multistage agrarian system analysis and diagnosis includes four stages: (1) studying the biophysical and environmental aspects of the agrarian landscape; (2) studying the history of farming systems; (3) analyzing the sociotechnical aspects of the farming system; and (4) analyzing the farming system's economic performance (Moquas-IPAD 2022). The analysis proceeds after first identifying coffee farmers' farming system and typology. The type of coffee farmer is determined by information about the farming system, agroecological zone, number of coffee trees, coffee yields, land area, infrastructure for coffee processing equipment, and cherry coffee income.

Assessment of adoption levels

Interviews with JASS farmers sought their practice of the nine-point GAP. They were classified as adopters if their practices exceeded the threshold of established standards. The data was processed using chi-square analysis. Table 1 shows each practice evaluated according to the criteria of GAP guidelines.

RESULTS AND DISCUSSION

Agroecological Environment

Temanggung Regency in Central Java Province, Indonesia, is mostly highlands with volcanoes like Mount Sindoro (3,151 masl) and Mount Sumbing (3,260 masl). It has a tropical climate with two seasons. The dry season lasts from April to September, while the rainy season lasts from October to March, with relatively high annual rainfall. Its weather is cold, with mountain air temperatures ranging from 20°C to 30°C. Tlahab is a coffee-growing village that has been designated as the first pilot project area for the development of JASS coffee plantations. It is located in a valley between two volcanoes with a suitable altitude and temperature, and it has the highest number of farmers and coffee tree populations.

Table 1. Criteria for adoption of GAP practices of coffee cultivation

No.	Practices	Criteria of GAP practices adoption
1	Plant spacing	Minimum plant space of 2.5 m x 2 m
2	Erosion control	Terraces used for steep land (> 8°)
3	Water and soil conservation	Frequent digging of *rorak* holes. *Rorak* holes hold fertilizer, leaf litter, and water, created near the main stem of coffee.
4	Shade tree planting	Having more than 35 trees/ha for medium shading
5	Fertilization	Applying organic fertilizer or manure 10-20 kg/tree twice a year (at the beginning and end of the rainy season)
6	Pruning	Regular pruning of coffee trees for shape and productivity
7	Pest and disease control	Applying organic or chemical pesticides, biological control, and breaking the pest life cycle
8	Intercropping	Growing seasonal crops such as tobacco and other food crops or trees
9	Harvesting technique	Picking of the mature-red coffee cherries

Understanding the biophysical environment is critical in agrarian system analysis and diagnosis. The first stage entails reading maps, followed by gathering information about the physical and agroecological environment, including topography, geology, pedology, hydrography, climate, and botany.

After collecting data, agro-ecological zones are classified to determine the relationships between the physical environ-ment, agricultural facilities, and land use (Moquas-IPAD 2022). Figure 3 shows how agroecological zones are formed.

The agroecological zone is divided into three: lowland, medium land, and highland on both sides of Mount Sindoro and Mount Sumbing. The lowland zone is filled with farmers' housing, warehouses, and places for processing crops from the farmlands. The medium land zone is the main area for growing JASS coffee, tobacco, and food crops for specialist and diversified coffee farmers, with 1.8 km on the side of Mount Sindoro and 2 km on the side of Mount Sumbing. Access to this zone is a rocky road with several small reservoirs. Rainforests with steep slopes dominate the highland zone. In this zone, rainforest

Figure 2. Map of Temanggung Regency and transect study area

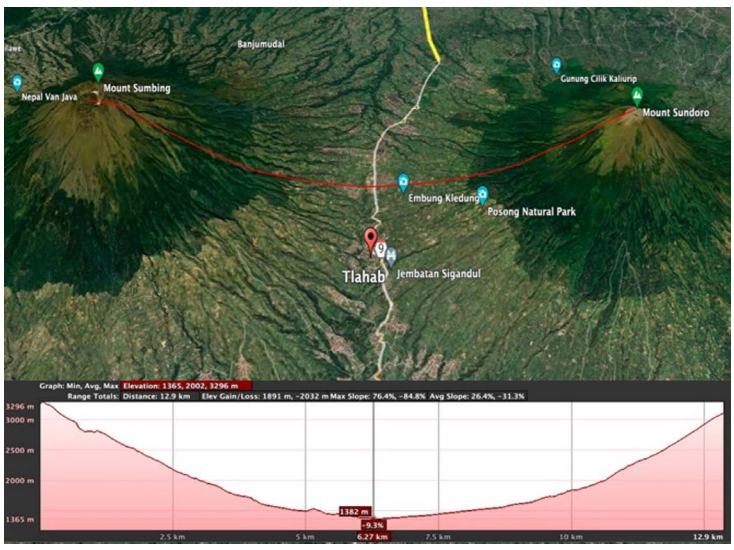
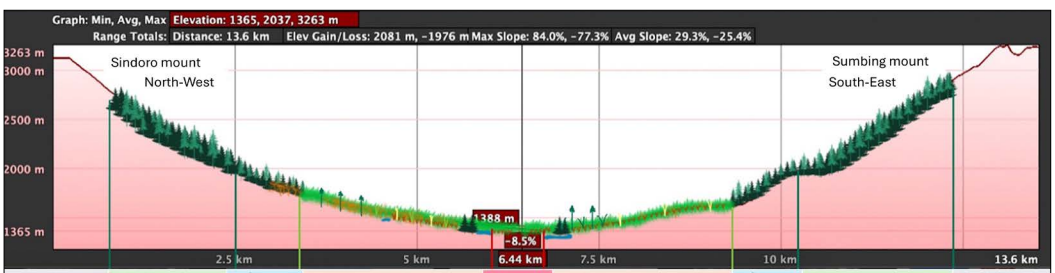


Figure 3. Agroecological zone in Tlahab between Mount Sindoro and Sumbing



Slopes	Forest slope	Steep slopes	Cultivation slopes	Villages	Cultivation slopes	Steep slopes	Forest slopes
Zone	Highland	Highland	Medium land	Lowland	Medium land	Highland	Highland
Distance	1.7 km	1.3 km	1.8 km	1.2 km	2 km	1.3 km	1.8 km
Crops	Dense rainforest	Rainforest + coffee	Coffee, tobacco, food crops, and trees	Home garden	Tobacco, food crops, less coffee and trees	Rainforest	Dense rainforest
Soils	Latosol & andosol	Latosol & andosol	Latosol & andosol	Latosol & andosol	Latosol & andosol	Latosol & andosol	Latosol & andosol
Facilities	Rocky and soil road	Rocky and soil road	Rocky Road	Asphalt road	Rocky road	Rocky and soil road	Rocky and soil road
Water	Rainfed	Rainfed	Rainfed, small reservoir	Spring, river	Rainfed	Rainfed	Rainfed
Problem	Extreme cold, wild boar	Extreme cold	Extreme weather: Strong winds and heavy rain	Land conversion	Extreme weather: Strong winds and heavy rain	Extreme cold	Extreme cold, wild boar
Obstacle	Tough access	Tough access	Potentially erosion		Potentially erosion	Tough access	Tough access

coffee farmers also plant and manage JASS coffee in collaboration with PT Perhutani, a state-owned enterprise operating in the forestry sector under the government of Indonesia. PT Perhutani provided a coffee cultivation area of 1.3 km on each side of the mountain. Access to the highland zone is difficult because of the steep, rocky, and soil road types. This area has no reservoir, and farmers rely only on rain.

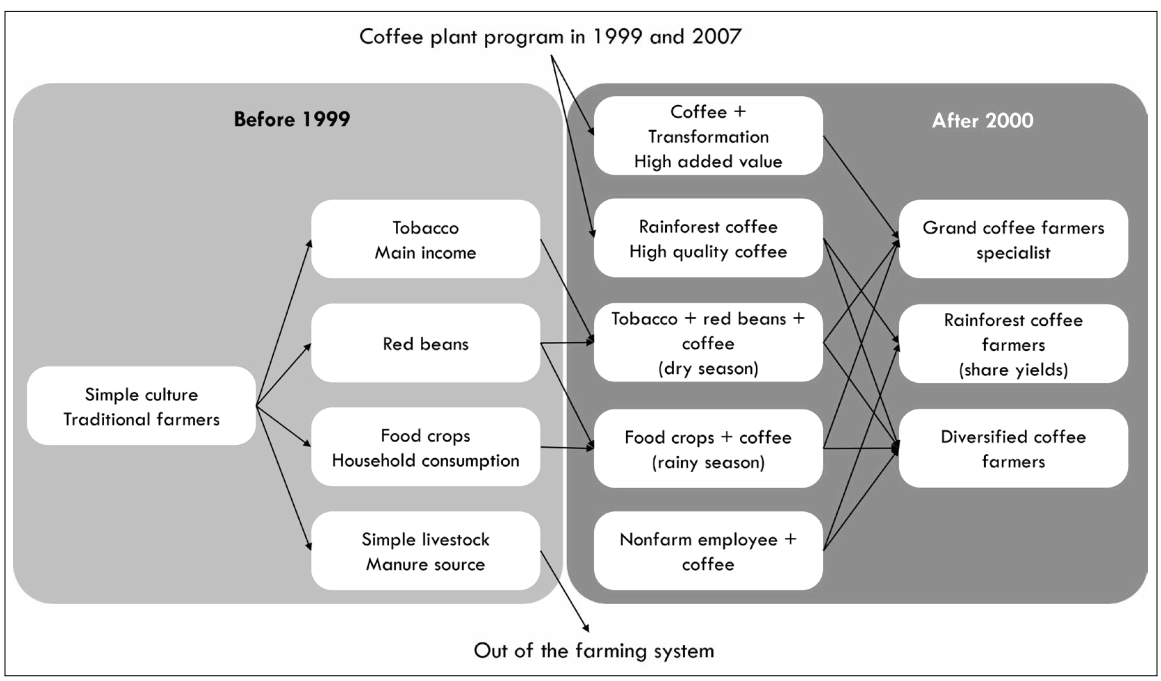
Farming System History

A farming system is a decision-making unit that includes the farm household, cropping, and livestock systems, all of which use land and labor to produce valuable products that can be consumed or sold. The diversity of farming systems today is closely linked to the past agrarian dynamics. Some factors cannot be attributed to agroecology alone. As a result, understanding the current state of the farming system requires delving deeper into the region's agricultural history, answering questions about the origins of differentiation. This phase's results create a typology of farming systems as products of history and the biophysical environment (Moquas-IPAD 2022). Figure 4 shows how farming systems in Temanggung differed before 1999 and after 2000.

Before 1999

Before 1999, farming systems in the study area were almost uniform. Tobacco plantations dominated this area, with traditional farming as the primary source of income. Farmers earned household income from tobacco sales, which they used to cover their annual living expenses. At that time, tobacco was still sold at reasonable and profitable prices, considered "green gold" back then because a kilogram cost more than a gram of gold. Red beans were also grown next to tobacco. It provided additional income, particularly for female farmers. Red bean is traditionally considered a woman's crop because it is planted and cultivated by women. Apart from being a source of additional income, red bean also has benefits as ground cover. Red beans are also thought to increase soil fertility by increasing nitrogen levels.

Figure 4 . Farming systems in Temanggung before 1999 and after 2000



After harvesting tobacco, farmers planted corn and a few additional vegetables during the rainy season, mainly for household consumption because tobacco income was sufficient to meet household needs. Most farmers kept small livestock in their homes. They would then process and use the manure to fertilize their tobacco fields. Livestock, such as goats and sheep, provided emergency savings as these could be quickly sold, rather than as a primary source of income. When tobacco prices were low in 1998, farmers sold their livestock in large numbers to cover their living expenses.

Traditional farmers relied on tobacco and corn as seasonal crops, and planting on steep slopes with few hardwood trees resulted in high erosion rates. Tobacco is a summer crop that requires full sunlight to maintain its quality. Consequently, farmers hesitated to plant too many timber trees to prevent erosion and water storage. A farmer reported that agricultural land on the slopes of Mount Sindoro-Sumbing was in critical condition, with erosion rates of 2 cm to 3 cm of soil or 53,72 t per year due to open agricultural land in the highlands for a long time (Purnamadjaya 2019).

The government and residents came together to address the issue of critical land on the slopes of Mount Sindoro and Sumbing by holding the *Pengembangan Model Usahatani Partisipatif* (Participatory Farming Business Model Development) program in 1999–2000. This program planted a million arabica coffee seedlings of the Kartika 1 and Kartika 2 varieties to increase the arabica coffee population as a conservation plantation and as an additional income source. Kartika was chosen because the trees are short, about the height of a mature tobacco plant, allowing the tobacco plants to receive full sunlight.

After 2000

In the early millennium, JASS trees effectively reduced soil erosion and increased water retention (Purnamadjaya 2019). However, at the time, JASS coffee products remained unpopular among enthusiasts and were consumed only at home. By 2012, demand for JASS coffee spread. The coffee tree became highly productive by the time it reaches 12 years old. Its increasing popularity has encouraged coffee businesses to thrive in Tlahab. The young villagers seized the opportunity by launching coffee brands such as Coffee Posong Two Heart, Toto Coffee, Kasminah Coffee, and Lawoek Coffee. JASS coffee achieved its pinnacle of success by exporting coffee beans to South Korea and the US.

While tobacco is still the primary commodity, its price has fluctuated, and some farmers have even incurred losses. Corn began to be substituted by vegetable crops with a short harvest age but better economic value. After harvesting red beans and tobacco at the end of the dry season, farmers have planted vegetables, such as cabbage, broccoli, chili, onions, garlic, and less corn during the rainy season. Unlike the ancient times, when farmers predominantly planted corn during the rainy season, farmers now planted various vegetables. They said this diversification has made them more secure in income and resilient to extreme weather changes. This system is what farmers have referred to as the Tlahab farming pattern (TFP). The TFP is the farming technique that combines cultivating annual crops such as JASS coffee with seasonal crops such as tobacco in the dry season and other food crops in the rainy season.

In 2007, PT Perhutani began to open opportunities to grow JASS coffee in the rainforests. PT Perhutani collaborated with LMDH (forest village community organization), an institution formed by village communities in or near the forest to regulate and meet their social, economic, political, and cultural needs. The elected members of the LMDH are those who have little or no land. This collaboration program aims to eradicate poverty in rural areas. Those who gain access to coffee JASS management are then referred to as rainforest coffee farmers. The system used is a profit-sharing system where the harvests of JASS coffee are divided into 70 percent for LMDH farmers and 30 percent for PT Perhutani. This collaboration is expected to improve the wellbeing of underprivileged farming households.

Table 2. Profile of JASS coffee farmers by type

Characteristics	Type of JASS Coffee Farmers		
	Specialist	Rainforest	Diversified
Age (years)	45.20	50.40	47.59
Education (years)	9.00	6.70	7.60
Experience (years)	15.30	14.30	19.03
Farm size (ha)	1.63	0.33	0.55
Plot (units)	2.90	1.10	1.41

Typology of JASS Farmers

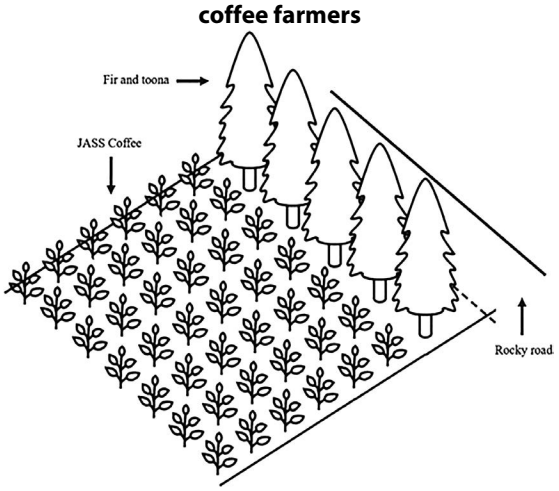
Changes in farming systems occur dynamically over time. The coffee farmers in the study area practice three types of farming systems: specialist, rainforest, and diversified. Table 2 shows the profile of each kind of JASS coffee farmer.

Specialist coffee farmers

The average age of this type of farmer is 45, with the highest level of education around nine years. The specialist coffee farmer has the largest farm at approximately 1.6 ha, compared with other types. The land is divided into three plots, located mostly in the medium land zone. Some of these farmers have access to small reservoirs, which allow them to irrigate their land, especially during the dry season.

Specialist coffee farmers have a larger population of JASS coffee trees than the two other types of farmers due to their larger farm sizes and significant capital. Some farmers use monoculture planting patterns on spare plots of land because they believe it will result in higher profit, as shown in Figure 5. Those with large farms may specialize in the monoculture of JASS coffee in some of their land. Farmers plant fir and toona trees near the coffee plantations to divide the land or as borders and to block the wind. These big trees are commonly found in low and medium land zones.

Figure 5. JASS coffee monoculture by specialist coffee farmers



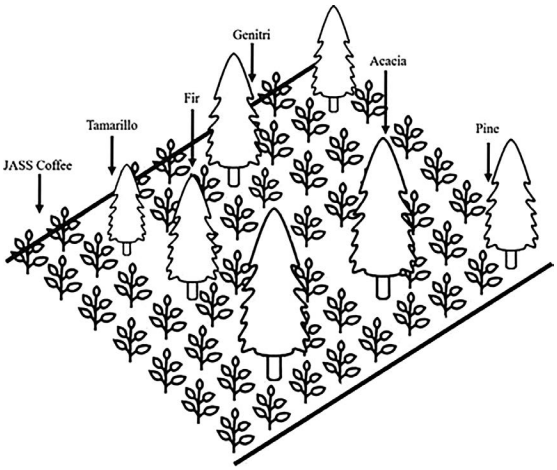
Source: Purnamadjaya (2019)

Rainforest coffee farmers

The rainforest coffee farmers have an average age of 50 years. They had a total education averaging 6.7 years, which is the lowest among the three farmer types. They are relatively new coffee farmers with minimal experience compared with the two other types. The rainforest coffee farmers are LMDH members who do not own land or have small private land. PT Perhutani has open access to plant JASS coffee on an average of 0.33 ha. The land located in the highland zone in rainforests is difficult to access, taking more than 30 minutes.

The start of JASS coffee cherry harvesting is late in the rainforest or the highland zone, beginning from August to September. Meanwhile, farmers harvest coffee trees grown in medium and lowland zones from June to August. The farmers explained that the longer growing period or slower maturation for JASS coffee in the rainforest allows the coffee fruit to ripen more optimally, resulting in higher quality. However, the productivity of rainforest coffee is the lowest. The challenge for this type of farmer is difficulty in accessing their trees, which hinders regular minor maintenance. They also work as farm laborers or construction workers. Hence, they have limited time to care for their coffee trees.

Figure 6. JASS coffee plantation in the rainforest



Source: Purnamadjaya (2019)

The Indonesian government has accepted the concept of coffee agroforestry managed by farmers under the forest as part of a social forestry program, with the goal of the community actively contributing to preserving the forest cover. Rainforest coffee farmers plant JASS coffee alongside woody plants in the rainforest, such as pine, acacia, fir, tamarillo, and genitri, as shown in Figure 6. They grow JASS coffee close together under the shade of dense rainforest trees. Acacia, fir, pine, and tamarillo are some of the dominant wood trees shading the JASS coffee plantation.

Diversified coffee farmers

The diversified coffee farmers are the type of farmers with the largest population in the study area. Their average age is 47.6 years old, with formal education averaging 7.6 years. They are the most experienced farmers, having cultivated JASS coffee for about 19 years. Most diversified coffee farmers own a single plot with an average land area of 0.55 ha. They use wide space between JASS coffee trees to plant other commodities as in Figure 7 (b).

This type of farmer primarily applied the TFP on their land. The TFP shows the combination of several commodities in one field by intercropping (Figure 7). JASS coffee is planted widely hence tobacco could fill the gap during the dry season and other food crops during the rainy season. JASS coffee is not the main income source but provides an additional income. The primary sources of income for diversified coffee farmers are tobacco and vegetables. As a result, their JASS coffee tree population is relatively small compared with other types of coffee farmers. Applying TFP addresses agricultural sustainability issues related to the economy and the environment. The diversified coffee farmer faces several challenges, including low productivity with their JASS coffee due to the coffee trees' old age and unfavorable weather. Moreover, coffee care still needs to be improved as farmers shift their focus to other commodities. Farmers use their agricultural work calendar based on dry and rainy seasons. Figure 8 illustrates this work calendar.

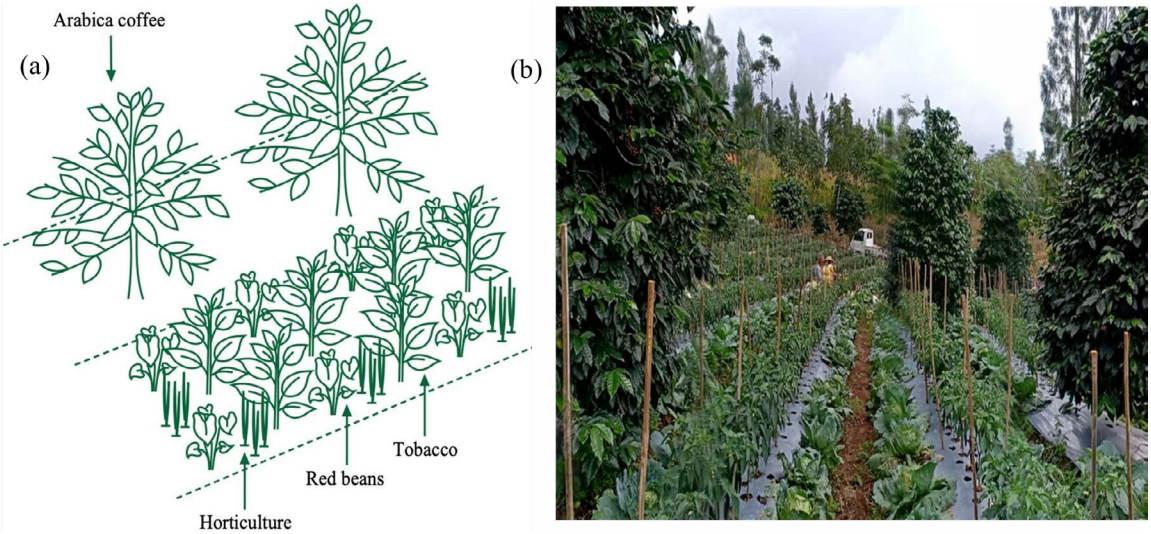
At the beginning of the rainy season, farmers would plant vegetables such as cabbage, broccoli, chili, or onion from November until December and harvest in February. After that, they would prepare the land for tobacco planting in March or the end of the rainy season and harvest in September during the dry season. August to September is the busiest month for farmers as they harvest and process tobacco. They harvest JASS coffee from June to August along with red beans. They fertilize JASS coffee after the tobacco process is completed in mid-September. The cycle then returns to preparing land and planting vegetables.

GAP Adoption

Indonesia has GAP guidelines for coffee plantations from the beginning to the end of the coffee production process. The GAP guidelines are stated in Regulation No. 49/Permentan/OT.140/4/2014, which includes nine cultivation practices. These practices are used to determine the level of compliance with GAP guidelines.

Table 4 shows no significant differences in the adoption of erosion control, pest and disease control, and red harvest among the coffee farmers. The practice of plant spacing and of intercropping significantly differ (at level 1%) among the types of

Figure 7. The Tlahab farming pattern as illustrated (a) and during the rainy season (b)



Source: Purnamadjaya (2019)

Figure 8. Work calendar under the Tlahab farming pattern

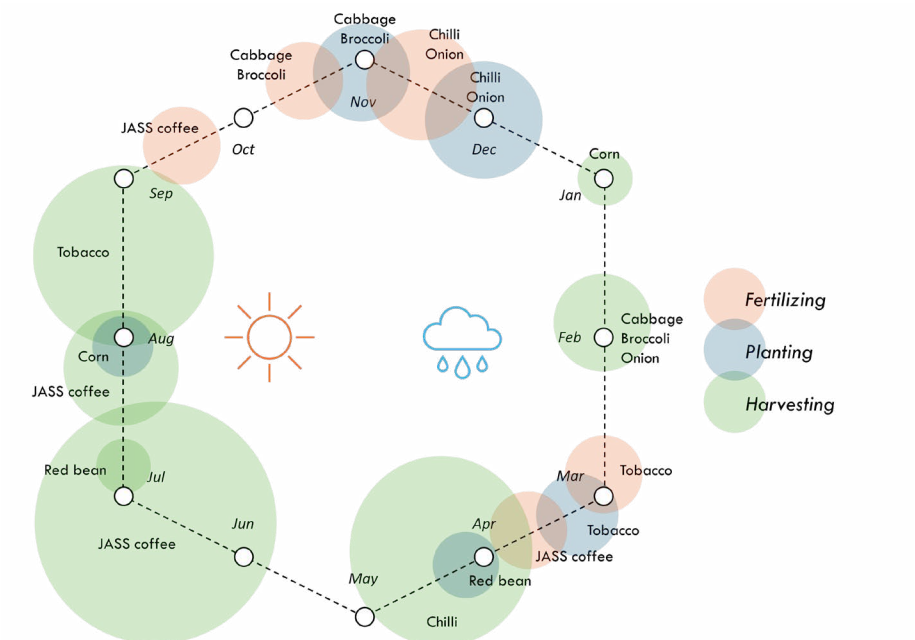


Table 3. Summary of modalities and GAP practices among coffee farmers in Temanggung, by type of farmer

Modalities and GAP	Specialist Coffee Farmers	Rainforest Coffee Farmers	Diversified Coffee Farmers
Main crops	Coffee and tobacco	Coffee	Tobacco and other food crops (cabbage, broccoli, chili, onions, garlic, and corn)
Additional crops	Cabbage, broccoli, chili, onions, garlic, and corn		Coffee
Main income	Coffee	Off-farm labor	Tobacco
Agriculture land	Large farm size (1.63 ha) Personal land-owned certificate	Marginal farm size (0.33 ha) With a government land use certificate	Small farm size (0.55 ha) Personal land-owned certificate
Agroecological zone	Low and medium land	Highland	Low and medium land
Labor	Family labor (2.73 persons) Hired labor (2.50 persons from rainforest coffee farmers) for coffee and tobacco cultivation	Family labor (1.5 persons) No hired labor	Family labor (2.15 persons) Hired labor (2.33 persons), from another city for tobacco harvesting and processing
Plant spacing	No limitation to apply recommended plant space	Limitation to apply standard plant space due to government regulation that rainforest trees cannot be logged	No limitation to apply standard plant space
Water and soil conservation (*rorak* holes)	Have family and hired labor to do *rorak* holes adoption	Have family labor to do high adoption *rorak* holes since these are used to collect leaves from the rainforest	*Rorak* holes adoption is low because there is no more room to make holes. All space has been used for tobacco and vegetable crops.
Shade trees	Some are planted in the middle of the field	Coffee trees planted under big trees in the rainforest that grow naturally Cover level by shade trees is relatively high	Limited land area Shade trees are planted alongside as a land boundary
Fertilizer	Have family and hired labor from rainforest Applied less than 20 kg/tree due to high price of fertilizer	Difficult to apply as no ability to pay for fertilizer The policy suggestion is fertilizer subsidy since they are under a privilege	Prefer to apply fertilizer for tobacco and food crops
Pruning	Have family and hired labor to prune the coffee plantation	No time for pruning as they work for specialized coffee and difficult access	Focus on tobacco harvesting and processing Have no time to prune their coffee trees

coffee farmers, with a high percentage of adopters exceeding 75 percent. Adoption of water and soil conservation, as well as shade trees, significantly differ, ranging from 30 to 50 percent of adopters. Fertilization and pruning practices significantly differ among other types of coffee farmers, with adoption rates below 25 percent.

Fertilization and pruning are critical practices for growing JASS coffee and for significantly increasing arabica coffee production (Siahaan et al. 2020). However, they remain low in adoption (Rowe et al. 2022). Data show that adoption of fertilization is low for all types of farmers at around 10.76 percent, and pruning is around 22.15 percent. Diversified coffee farmer types carry out the most deficient fertilization and pruning practices. Specialist coffee farmers dominate the practice of implementing GAP cultivation.

These are considered to be the primary causes of the low productivity of JASS coffee. Farmers use low fertilization practices because they believe that fertilizer for tobacco and vegetables benefits coffee trees. Rising fertilizer costs also constrain them, as their income does not allow them to purchase fertilizer designed explicitly for JASS coffee plants. Pruning is associated with labor because it requires significant manpower. The more labor you have, the more pruning is likely. This is the case for specialist coffee farmers who can afford to hire permanent employees and freelancers, so their rate of pruning is high (63.64%).

Comparative Performance of the Different Types of Coffee Farmers

The three types of JASS coffee farmers have distinct characteristics and adoption rates of GAP. Table 5 presents the comparative performance of each type of JASS coffee farmer.

Table 5 shows that the average number of productive coffee trees, total coffee cherry yield, coffee cherry yields per tree, and total coffee cherry income significantly differ among the three types of JASS coffee farmer at a level of significance of one percent.

The specialist coffee farmers have an average number of productive JASS coffee tree owners, with 653 trees being cultivated intensively. They have the highest percentage of GAP adoptions with access to water. These are essential aspects that can boost the production of JASS coffee cherries. The productivity of their JASS coffee trees is the highest compared with those of the

Table 4. Number and percentage of GAP adoption by type of coffee farmer

Practices of GAP Guidelines	Type of Coffee Farmers						Total		Chi-square	P-value
	Specialist		Rainforest		Diversified					
	No.	%	No.	%	No.	%	No.	%		
No. of farmers	22	100.0	26	100.0	110	100.0	158	100.0		
Plant spacing	19	86.4	14	53.9	92	83.6	125	79.1	12.1074***	0.002
Erosion control	18	81.8	21	80.8	84	76.4	123	77.8	0.4703	0.790
Water and soil conservation	16	72.7	23	88.5	28	25.4	67	42.4	43.8043***	0.000
Shade trees	12	54.5	13	50.0	27	24.5	52	32.9	11.5889***	0.003
Fertilizer	4	18.2	7	26.9	6	5.4	17	10.8	11.5608***	0.003
Pruning	14	63.6	10	38.5	11	10.0	35	22.1	35.3850***	0.000
Pest and disease control	10	45.4	5	19.2	39	35.4	54	34.2	11.5608	0.142
Intercropping	20	90.9	4	15.4	110	100.0	134	84.8	117.6136***	0.000
Red harvest	22	100.0	26	100.0	110	100.0	158	100.0		

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 5. Coffee yield and income among different types of JASS coffee farmers

Particulars	Type of JASS Coffee Farmers			F	Prob>F
	Specialist	Rainforest	Diversified		
Number of farmers	22	26	110		
Average number of productive coffee trees	652.9	225.5	181.5	49.1***	0.0000
Average coffee cherry yields/farm (kg/farm)	1,304.0	128.9	283.0	44.3***	0.0000
Average coffee cherry yields/tree (kg/tree)	2.0	0.6	1.5	12.3***	0.0000
Average coffee cherries income (IDR)	11,968,364	244,980	3,381,456	10.1***	0.0001

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

other types of farmers, around 2 kg/tree. Specialist coffee farmers harvest 1.3 t of coffee cherries from the productive coffee trees they planted. Hence, it can also be ascertained that specialist coffee farmers can generate a household income of IDR[2] 11,968,364 (USD 770) from JASS coffee cherries, which is the highest compared with others.

The rainforest coffee farmers own an average of 225 productive coffee trees under the rainforest area. They have the lowest productivity of JASS cherries compared with others, around 0.6 kg/tree. Low productivity is due to minimal maintenance on account of the difficulty in accessing the trees. In addition, they have limited time to work on their farms because they concurrently work as farm laborers or construction laborers. This is exacerbated by extremely cold weather that causes crop failure due to blackened coffee flowers that subsequently shed. They try to keep the coffee from dying by applying fertilizer. However, the results are less encouraging. The JASS coffee cherries can contribute to a household income of IDR 244,980 (USD 15.44). The low income of rainforest coffee farmers compared with other types of farmers is due to the rising cost of fertilizer and the difficulty of accessing the rainforest.

The diversified coffee farmers have the least productive JASS coffee trees, approximately 181. They grow tobacco during the dry season and other food crops during the rainy season. The limited land area makes them diversify their crops, grown as a source of income, to avoid dependence on a single commodity. They farm JASS coffee as source of side income to finance purchasing fertilizer for tobacco or vegetables. They do not pay much attention to GAP adoption. The productivity of their JASS coffee trees is around 1.5 kg/tree, which is still below that of the specialist coffee farmer. They produce an average of 283 kg of JASS coffee cherries. Their income from JASS coffee cherries is IDR 3,381,456 (USD 212).

CONCLUSION

Farming systems change over time. Before 1999, the simple farming system in Temanggung consisted of planting tobacco and red beans during the dry season, switching to corn during the rainy season, and keeping livestock for emergency savings and manure. However, erosion was a significant issue because wood trees were few. Farmers grew JASS coffee in large quantities and positioned it as a conservation plant while providing a new income source. After 2000, they grew JASS coffee alongside tobacco and red beans during the dry season, followed by more diverse food crops during the rainy season. JASS farmers are classified as specialist, rainforest, and diversified coffee farmers. Among the GAP practices for JASS coffee, plant spacing and intercropping had adoption rates greater than 75 percent. Water and soil conservation and planting of shade trees had 30 to 50 percent adopters. On the other hand, fertilizer and pruning

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had adoption rates below 25 percent. Specialist coffee farmers led the practice of implementing GAP cultivation, demonstrating higher yields and income from coffee cherries compared with the two other types of coffee farmers.

RECOMMENDATIONS

Comprehensive training on the importance of GAP is needed. Fertilization and pruning are major concerns for all types of farmers, especially for diversified coffee farmers. Since GAP adoption is relatively high, specialist coffee farmers could be given postharvest training including good coffee processing techniques, packaging, and marketing. Access to capital for agricultural inputs for better coffee cultivation practices could be provided to rainforest coffee farmers who are less privileged.

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