Strategies on technology management for coffee smallholder to promote the smart farming implementation

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Abstract. Smart farming is becoming increasingly important in providing technology infrastructure for the coffee agribusiness to develop a competitive value chain. On the other side, most coffee smallholders are characterized by limited access to technology and low technology adoption. As development and exploitation of technological capabilities, technology management would be a strategic way to promote smart farming implementation. Hence, this study aims twofold: (1) to identify the constraints in smart farming implementation, and (2) formulate technology management strategy in supporting smart farming for the coffee smallholder. The study was conducted in West Lampung, and the analysis method used pairwise comparison by using Saaty’s scale. The analysis reveals that respondents’ constraints related to knowledge and skills, technology, information, capital, organizational, and resources aspects. The results of this study provide useful information about technoware, humanware, inforware, orgaware, and cybersnetware, as components of technology management, to support smart farming for the coffee smallholder.

1. Introduction

Smart farming is a strategic approach to increasing agricultural competitiveness and sustainability. Improved farm-level productivity as a process upgrading is a strategy to improve Indonesia contribution in global coffee value chains beside product upgrading (quality differentiation) and functional upgrading (downstream processing of raw beans) [1].

Smart farming is the application of information and data technologies for optimizing complex farming systems. Technologies are used to improve the production quality and data traceability, minimize costs and make the activity more efficient and competitive [2]. Integrate technology into the overall coffee production system is very important. On the other side, most coffee smallholders are characterized by limited access to technology and low technology adoption.

As development and exploitation of technological capabilities, technology management would be a strategic way to promote smart farming implementation. Hence, this study aims twofold: (1) to identify the constraints in smart farming implementation, and (2) formulate technology management strategy in supporting smart farming for the coffee smallholder.
2. Research method
The study used primary and secondary data. Secondary data used publication in 2019 and 2020 from Ministry of Agriculture and the Central Bureau on Statistics. Describing constraints to implement smart farming is constructed by using a case study. Observations were carried out in Sumberejo village, West Lampung in 2019. The number of respondents is 24 smallholders.

The analysis method used pairwise comparison by using Saaty’s scale (Table 1). Instead of a numerical judgment, relative verbal appreciation is used and recorded in a positive reciprocal matrix [3]. Analytical stages include: (1) construct a matrix to employ pairwise comparison, (2) compare factors. The intensity of importance of each factor is required since factors are not equally important by using Saaty Scale (Table 1), and (3) calculate the value of Pairwise Matrix for each pairwise comparison matrix. Once the Pairwise Matrix (A) is constructed, therefore continue by deriving from A the normalized pairwise comparison matrix $A_{\text{norm}}$, by making equal to 1 the sum of the entries on each column, i.e. each entry $a_{jk}$ of the matrix $A_{\text{norm}}$ is computed as:

$$a_{jk} = \frac{a_{jk}}{\sum_{i=1}^{m} a_{ik}}$$

(1)

The criteria weight vector $w$ (that is an m-dimensional column vector) is built by averaging the entries on each row of $A_{\text{norm}}$, below:

$$w_j = \frac{\sum_{i=1}^{m} a_{ij}}{m}$$

(2)

| Intensity of importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two activities contribute equally to the objective |
| 3                       | Moderate importance | Experience and judgment strongly favor one activity over another |
| 5                       | Strong importance | Experience and judgment strongly favor one activity over another |
| 7                       | Very Strong or demonstrated importance | Activity is strongly favored, and its dominance demonstrated in practice |
| 9                       | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Intermediate values between the two adjacent judgment | When compromise is needed |

3. Result and discussion
3.1 Coffee plantation development in West Lampung
The majority of coffee in Indonesia is robusta coffee, reaching 80.89% or 1.02 million hectares, while Arabica coffee only 242.15 thousand hectares or 19.11% [4]. The smallholder coffee plantation area was 96.63% with an area of 1,210.7 thousand hectares in 2018 [5]. Based on the farming category, the highest coffee productivity was government coffee plantation at 822.26 kg/ha, followed by private plantation at 744.46 kg/ha. In comparison, the lowest productivity was smallholder plantation at 740.46 kg/ha [4].

For many years in the Lampung Province, the coffee plantation has been developing, generally for Robusta coffee, suitable for development in lowland areas. The development and application of
sustainable coffee cultivation and post-harvest techniques have already designed for the plantation development in Lampung Province.

Robusta coffee plantations in West Lampung are spread across 15 districts, 5 sub-districts and 131 villages. West Lampung Regency is the largest Robusta coffee plantation in Lampung Province, followed by Tanggamus, North Lampung, and Way Kanan Regencies. The coffee production in West Lampung Regency is 51,484.6 tons [6].

Most of the coffee farmers were elderly farmers who manage coffee plantations from generation to generation. A case study in Sumberejo Village showed that the respondents’ age was dominated at 53-58 years old (33.33%). Most of the farmers experienced in coffee farming. Around 83.33% of farmers have experienced coffee plantations for more than 11 years, 50% have more than 17 years of experience, and only a few have experience under 5 years (4.17%).

Most productive coffee is between 7 to 20 years of age. The respondents’ coffee plantation that more than 21 years old reached 66.66%, which productivity starts to decline. The productivity for all respondent is lower than one hundred per ha or under the potential number. Around 50% had productivity at 0.8-1 ton/ha.

Referring to the technology adoption, some respondents only adopt Good Agricultural Practises (GAP) in partial (37.50%). Most of the coffee cultivation in West Lampung is still cultivated in traditional approach which is characterized by (1) use of local clones with low productivity, (2) without shade, (3) fertilization is not carried out according to recommendations, (4) pest and disease control is not carried out and (5) crop maintenance, such as irregular pruning and weed weeds, are not following the recommendation [7].

All respondent has not had certification of sustainable coffee yet. The certification scheme is likely chosen due to a price premium, focuses on environmental conservation, offers price differentials between certified and uncertified coffee, targets farmers in a group or cooperative, values fairness, offers a price differential based on the size of the coffee beans, and offers no formal contracts or credit options [8]. However, certification is only weakly institutionalized among farmers, and farmers’ knowledge about the certification schemes is low [8]. Obstacles to implementing a sustainable certification system at the farmer level include the availability and access of information, farm management, technology availability and access, capital availability and access, and land ownership and status [9].

3.2 Smart farming in the coffee farming system

Smart farming is a farming management concept using modern information and communication technologies for crop cultivation and food production system [10]. Some of the technologies that farmers can use include sensing technologies, software applications, communication technologies, robotics and automation, and data analytics for a decision support system. Smart farming is concerned with using advanced technology and considering new technologies concerning the diversity of crop and livestock systems and related markets and policies [11]. Introducing policies to encourage farm diversification is among the options to improve coffee farming’s profitability while ensuring environmentally-friendly crop management practices [12].

The problems faced in coffee development relate to climate change, old plants, land degradation, also pests and diseases, while competition is getting tougher with demands for added value. Smart farming helps overcome the treat, reduce overall costs, improve the quality and quantity of products, and achieve the sustainability of agriculture. Related to climate change context, smart farming implementation include adding compost to restore productivity; improve the soil texture and incorporate carbon content into the soil; establishing an agroforestry system with shade trees; changing wastewater treatment; improving the management of coffee pulp; and establishing the correct density of coffee trees per hectare, according to fertility and slope [13]. Using technologies makes agriculture more beneficial for farmers by reducing crop production and increasing farmers’ income through high crop yield [14].
3.3 Constraints in smart farming implementation

The analysis reveals that respondents’ constraints related to knowledge and skills, technology, information, capital, organizational resources, and resources (Table 2).

**Table 2. Constraints in smart farming implementation**

| Aspects         | Constraints                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| Knowledge and skills | Lack of knowledge acquisition                                                 |
|                  | Low awareness of smart farming                                               |
| Technology       | Limited access to technology                                                  |
|                  | Routines changes in agricultural operations                                  |
| Information      | Limited agricultural extension                                                |
|                  | Lack of smart farming-related information                                    |
| Capital          | High initial investment                                                       |
|                  | Long Return of Investment periods involved with the technologies             |
|                  | Limited access to capital or investment                                      |
| Organizational   | Low of collective efficiency                                                  |
| Resources        | Low institutional investment in agricultural communities                     |
|                  | Small land size                                                              |
|                  | Lack of resources                                                             |

The variables potentially affecting adoption of precision agriculture technologies include operator age, number of row crop acres in operation, average yearly gross farm income, the use of irrigation, and the producer’s use of a cell phone with internet access [15]. Several row crop acres in operation and the usage of a cell phone with internet access had a statistically significant effect on the number of technologies adopted. Determinants factors of Climate-Smart Agriculture adoption level among small-scale farmers are education, farm income, income from non-farm sources, distance from home to the plantation, contact with agricultural extension agents, exposure to media, marital status, production activity, membership of an agricultural-related group and perception of the effect of climate change [16].

Data showed that the farmers had enough experience cultivating coffee because almost a third of their age is in the coffee farming system. However, these years of experience can become an obstacle to accepting new technologies. Most coffee plantations are smallholder plantations, whose ownership areas range around 0.5-2 ha/household. Narrow land ownership will affect technical efficiency and economic efficiency in the use of advanced technology.

The optimal production of coffee plants is 10-15 years and will decline after that. As many as 50% of the plants are more than 21 years old and need to be replanted. Replanting requires financial support, and only open-minded farmers may complete well. Rejuvenation is costly. In the condition that the number of farmers who are more than 47 years old reaches 62.5% and has limited capital support, then replanting according to GAP will be difficult.

Coffee cultivation requires a large investment, especially at the beginning of development. The cost component includes the provision of shade plants. Coffee plants require shade plants which account for about 30% of the amount of coffee grown. The capital for coffee investment in the survey location came mostly from their capital (37.50%), followed by supporting capital (33.33%) from government, and borrowing from families (29.17%). Borrowing from official financial institutions, moneylenders and traders were not found. This condition was indicated that farmers are more risk-averse.

The area of coffee plantations owned by farmers varies based on the sources of financing. Coffee farmers who rely on their capital have a narrower area of coffee plants (0.60 ha). In comparison, respondents who receive capital from government assistance or loans from families have an area of 0.70 ha and 0.77 ha, respectively.

Extension for coffee plantation was relatively limited because of the extension’s status as extension agents for all agricultural commodities and focuses on food crops. The extension material is mostly
about cultivation aspects and how to apply GAP at the farmer level. Although smart farming could mitigate climate change effects, the finding showed that the farmers were focused mainly on the potential profit and cost reduction when adopting smart farming technologies.

3.4 Technology management for smallholder as strategies to implement smart farming

The application of smart farming in smallholder plantations is based on smallholder plantations and farmer organizations’ conditions. A farmer organization can be in the form of a farmer group, or a cooperative. The farmers’ organization has an important role in innovation and research on decision support systems and technical solutions to current problems. Overall, technical solutions need to become smarter and integrated into farm management systems [17].

The application of smart farming in smallholder coffee plantations can be pursued by increasing GAP application and applying sustainable coffee certification by integrating technology in various processes in it. GAP application will build a more efficient agricultural system, and the sustainable coffee certification will build competitiveness in an increasingly competitive market, while both supported by technology.

Smart farming involves many tools and technologies which are used for automation and real-time monitoring of farming activities. Smart farming application in the coffee farming system includes crop health monitoring, soil nutrient measurement, crop yield prediction, pesticides management, fertilizer management, and irrigation management. Therefore, the application must be based on the coffee farming community supported by the government and other institutions. Technology management will serve a knowledge-transfer mechanism from experts such as agronomists, meteorologists, input dealers, pathologists, to farmers.

Technology management will be related to the system’s components, hence designing technology management for coffee smallholders to promote smart farming implementation will focus on developing strategies and prioritizing technology management components. Conceptually technological system components are divided into [18]: (1) object-embodied component (technoware) which refers to the physical capital utilized for various work packages; (2) person-embodied component (humanware) which refers the person-embodied art-of-doing-type technological system components; (3) record-embodied component (inforware); (4) teamwork-embodied component (orgaware); and (5) cyberspace-embodied component (cysnetware). Technology management for smallholders as strategies to implement smart farming is directed at providing, managing, and utilizing the five components based on the conditions of coffee smallholder. It can be detailed and analyzed by using pairwise comparison, as seen in Table 3.

Orgaware (0.430) is a technology component that has a higher relative importance to others. Establish mechanisms for accessing farm financing and promote strategic partnerships to increase farmer group social capital and networks are priority strategies. Strategy formulation is based on the constraints of implementing smart farming related to high initial investment and long Return of Investment periods involved with the technologies. Promote strategic partnerships to increase farmer group social capital and networks are expected to strengthen farmer organizations and develop networks for social capital development for coffee farmers’ capacity building and overcome constraints on limited access to capital or investment.

Since the orgaware component has already run completely, the technoware (0.333) and humanware (0.116) components will become the next focus. At this stage, the availability of and access to smart farming technology and capacity building for smallholder coffees is needed to be enhanced. This strategy aims to build a sustainable adoption of smart farming.
Table 3. Strategies for smart farming implementation

| Components of Technology | Value | Strategies                                                                 | Value |
|--------------------------|-------|----------------------------------------------------------------------------|-------|
| Technoware               | 0.333 | Promote and implement crop superior varieties                             | 0.036 |
|                          |       | Promote Crops Livestock integration as an integrated farming system         | 0.114 |
|                          |       | Promote water harvesting and storage                                       | 0.072 |
|                          |       | Promote soil management in agricultural landscapes                         | 0.072 |
| Humanware                | 0.116 | Knowledge management and capacity building in smart farming                 | 0.050 |
|                          |       | Increase internet literacy for coffee smallholder                          | 0.025 |
| Inforware                | 0.074 | Implement farm management record keeper                                    | 0.032 |
|                          |       | Build capacities on data collection and information management              | 0.032 |
|                          |       | Build accessible data and information management system                     | 0.032 |
| Orgaware                 | 0.430 | Establish mechanisms for accessing farm financing                           | 0.186 |
|                          |       | Strengthen collaboration between stakeholder on enforcing smart farming implementation | 0.093 |
|                          |       | Promote strategic partnerships to increase farmer group social capital and network | 0.186 |
| Cysnetware               | 0.047 | Develop Internet of Things (IoT) model for coffee smallholder               | 0.020 |
|                          |       | Develop a Geospatial analysis model for the decision support system of the coffee smallholder | 0.020 |

4. Conclusion
The application of smart farming in smallholder plantations is affected by conditions of smallholder plantations and farmer organizations. The application of smart farming in smallholder coffee plantations can be pursued by increasing GAP application and applying sustainable coffee certification by integrating technology in various processes. Smart farming application in the coffee farming system includes crop health monitoring, soil nutrient measurement, crop yield prediction, pesticides management, fertilizer management, and irrigation management. Smart farming involves many tools and technologies which are used for automation and real-time monitoring of farming activities. The constraints faced by coffee smallholder include knowledge and skills, technology, information, capital, organizational, and resources. Technology management for smallholders as strategies to implement smart farming is directed at providing, managing, and utilizing the five components, including technoware, humanware, inforware, orgaware, and cysnetware.

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