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A socio-entrepreneurship empowerment model for coffee farmers to sustain soil fertility practices

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Abstract The findings showed that external assistance is shown to be a crucial for encouraging socio-entrepreneurship among coffee growers working to sustain soil fertility in Rejang Lebong Regency. Key drivers included financial access, cooperatives, and government initiatives, which significantly boost socio-entrepreneurship ($\beta = 0.46$, $p < 0.01$). Access to financing and stable coffee prices enabled growers to invest confidently in sustainable land management. Farmer capacity, mainly through education, training, and agricultural knowledge, was also important ($\beta = 0.20$, $p = 0.05$) and leaded to a better understanding of sustainable practices and enhanced use of digital tools for technical and market information, improving entrepreneurial readiness. Notably, the direct effect of soil fertility practices alone on socio-entrepreneurship was not significant. Conservation strategies such as terracing, shade planting, and composting with coffee waste are seen as standard for productivity but not as entrepreneurial opportunities. Factors, such as limited technology, restricted markets, and weak economic incentives, prevented the farmers from turning ecological practices into profitable ventures. Overall, advancing socio-entrepreneurship in coffee farming requires combining environmental sustainability with social and economic support. The most important enabling conditions are found to access and finance, strengthened farmer capacity, and transparent, stable markets.

Keywords: Causal loop diagram, Coffee farmers, Socio-entrepreneurship, Soil fertility, Sustainability

Introduction

Indonesia is one of the largest coffee producers in the world (758.7 thousand metric tons), with Sumatra being one of the main coffee-producing regions. Among coffee-producing areas in Sumatra, Bengkulu Province is included in the *five-star category* of the largest coffee producers in Indonesia. Rejang Lebong Regency in Bengkulu Province stands out as a significant coffee production center with an area of 23,104 hectares of robusta coffee plantations,

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with a production of more than 18,000 tons per year. In addition, Arabica coffee plantations cover an area of 529 ha, which produces as much as 200 metric tons per year. Coffee is not only a leading commodity that supports the local economy but also a source of livelihood for thousands of farmers. Land fertility for coffee in Rejang Lebong Regency is influenced by the characteristics of volcanic soils rich in essential minerals, such as nitrogen, phosphorus, and potassium, which support the growth of coffee plants. This area has an altitude of approximately 800–1,500 m above sea level with relatively cool temperatures (18–25°C), ideal conditions for coffee cultivation, especially Arabica and Robusta varieties. In addition, the texture of the soil, which is generally sandy clay to clay-clayed, allows for good drainage while maintaining the soil moisture needed by coffee plants. The high content of organic matter, the result of the decomposition of natural litter under the shade of a protective tree, also contributes to the fertile soil structure (Kusmana and Yentiana, 2021).

Despite its great potential, the sustainability of coffee production in this area faces serious challenges. In particular, there are issues related to declining soil fertility, such as the excessive use of chemical fertilizers and deforestation. These practices can reduce soil fertility in the long term (Tsaniyah and Daesusi, 2020; Wahyuni and Suranto, 2021). Unsustainable agricultural practices, including the excessive use of chemical fertilizers and failure to apply soil conservation techniques, will lead to land degradation. This, in turn, negatively impacts farmers' productivity and welfare (FAO, 2020). In addition, cleaning land with herbicides or grass poisons leaves traces of residue. These residues can also have fatal consequences for coffee that will be marketed abroad.

To overcome this problem, an innovative approach is needed that focuses not only on the technical aspects of agriculture but also strengthens the social and economic capacity of farmers. One promising approach is socio-entrepreneurship empowerment, or farmer empowerment based on social entrepreneurship in the Rejang Lebong coffee plantation area. Anh *et al*. (2019) xamine how social entrepreneurship plays a role in overcoming poverty among coffee farmers in Vietnam. The findings from these studies offer vital perspectives on designing a socio-entrepreneurship empowerment model for coffee farmers in the Rejang Lebong Regency to maintain sustainable soil fertility practices. This model emphasizes the integration of the three pillars of sustainability: environmental, economic, and social. Social entrepreneurship is also an important factor in supporting agricultural sustainability.

Socio-entrepreneurship in coffee farming faces both internal and external challenges. While the relatively low levels of education among coffee farmers hinder the adoption of sustainable practices, their progress is also impeded by limited access to information and training, as well as insufficient knowledge of

sustainability (Altierl, 1997; Doherty *et al*., 2014; Pretty, 2008). Sumartono *et al*. 's (2019) research demonstrates that socio-entrepreneurship can reduce poverty among Vietnamese coffee farmers. This finding offers insights for empowerment models in Rejang Lebong, which aim to maintain soil fertility by incorporating environmental, economic, and social sustainability. Furthermore, financial support can boost global sustainable coffee production (ICO, 2024).

Key barriers include limited access to effective cooperatives, inadequate capital for adopting new technologies and sustainable practices, uneven government support that often does not meet farmers' specific needs, and price fluctuations in the global coffee market. These obstacles hinder collaboration, empowerment, and economic stability, highlighting the need for innovative marketing strategies to support coffee farmers' welfare.

To develop an effective empowerment model, identifying the relevant socio-entrepreneurship approach is crucial. The strategy for Rejang Lebong farmers should prioritize agroecological techniques proven locally, such as shade management with native trees, organic composting using farm residues, and integrating leguminous cover crops. Promoting these methods ensures that the empowerment strategy is actionable and relevant. This study aims to provide policy recommendations for stakeholders to enhance coffee farming sustainability in the Rejang Lebong Regency.

This research employed a socio-entrepreneurship approach that merges economic, social, and environmental concepts in coffee farming. The aim was to empower farmers to manage land sustainably through a social business model involving communities and stakeholders and to formulate an empowerment strategy based on sustainability and innovation principles.

Materials and methods

This study was conducted in the Kayu Manis Village, Rejang Subdistrict, Rejang Lebong Regency. This location was chosen because of its relatively high coffee production, estimated at 3,380 metric tons in 2024. The sample of respondents in this study consisted of 120 coffee farmers, selected purposively based on the analysis tool, the partial least squares-structural equation model (PLS-SEM). PLS-SEM requires a minimum of ten times the number of indicators (Hoogland and Boomsma, 1998). The survey was conducted at the research location using a closed questionnaire with ordinal data and a Likert scale of 1–5.

The first data analysis was conducted using the PLS-SEM analysis tool with the following stages:

1. Validity and Reliability Tests
2. Direct and Indirect Influence Test
3. Mediation Analysis

Table 1. Leave variable then variable manifest

Laten Variable	Code	Manifest Variable
Sustainability of Soil Fertility Practices (X1)	X11	Use of organic fertilizers
	X12	Crop rotation
	X13	Soil conservation techniques
	X14	Utilization of coffee waste for fertilizer
Socio Entrepreneurship (Y)	Y1	Social mission in farming
	Y2	Social innovation in coffee production/marketing
	Y3	The Financial Sustainability of Coffee Farming
	Y4	Collaboration with cooperatives, government, private sector
Farmer Capacity (X2)	X21	Farmer education level
	X22	Training that has been attended
	X23	Knowledge of sustainable farming practices
	X24	Access to agricultural information
External Support (X3)	X31	Support from cooperatives or farmer groups
	X32	Access to capital and financing
	X33	Government program for sustainable agriculture
	X34	Coffee price stability in the market

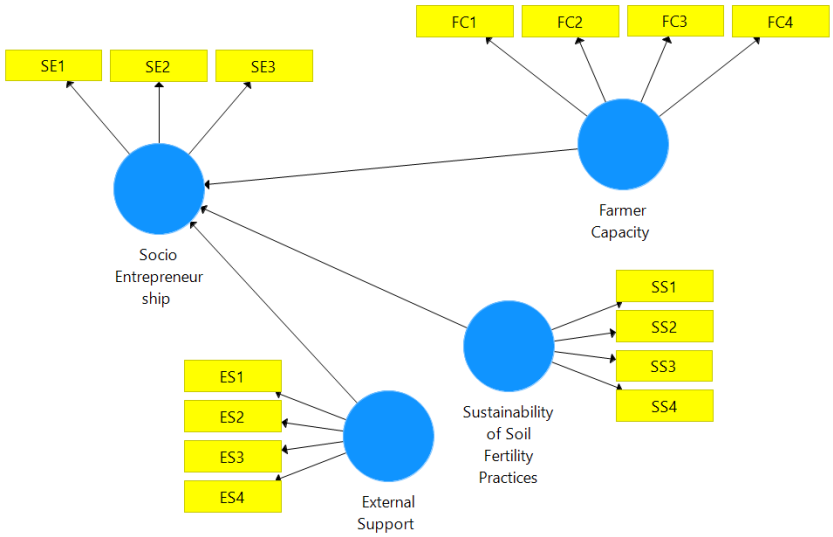

Figure 1. The structural equation model in this study

The study was based on the following hypothesis:

- H1: Sustainability of soil fertility practices (X1)positivelyeaffectse socio-entrepreneurship (Y).
- H2: Farmer capacity (X2) has a positive effect on socio entrepreneurship (Y).
- H3: External support (X3) has a positive effect on socio entrepreneurship (Y).

Group model building (GMB) was used to determine the optimal model in socio-entrepreneurship to maintain the fertility of coffee fields. This method focused on group discussions (FGDs) with farmers and stakeholders to identify key factors and relationships between variables. The stages of the GMB included identifying key factors related to socio-entrepreneurship, farmer capacity, and external support; preparing alternative models based on the perspective of the community; and evaluating and validating the model by comparing the results of partial least squares structural equation modeling (PLS-SEM). The analysis tools included a causal loop diagram (CLD) to visualize variable relationships and software such as Vensim for model simulation. This approach integrated PLS-SEM results and field perspectives to produce a more applicable and contextual model for coffee farmers.

Results

Demographic characteristics of the respondents

The study sample comprised 120 coffee producers with a mean age of 47.30 years (Table 2). The respondents predominantly comprised men (73.33%) and women (26.67%). Most farmers possessed an education level below a bachelor's degree (80.83%), while 19.17% of respondents had no formal education, and none had an education exceeding a bachelor's degree. Coffee farmers in this study had an average of 23.30 years of farming experience. Moreover, the mean area of coffee land cultivated by farmers was 1.27 hectares. The average annual income of farmers in the coffee industry amounted to IDR 52,534,133.60.

Table 2. Profile respondents

Item	Number of people (n=120)	Percentage (%)
Average of age	47.30	100.00
Gender		
Male	88.00	73.33
Female	32.00	26.67
Education		
Below a bachelor's degree	97.00	80.83
Higher than a bachelor's degree	-	-
Uneducated	23.00	19.17
Average of coffee farming experience	23.30	100.00
Average coffee planting area (ha)	127.00	100.00
Average Revenue per year (IDR)	52,534,133.60	100.00

Factors that influence the formation of socio-entrepreneuship in maintaining soil fertility by PLS-SEM

Outer model analysis

Construct reliability was assessed on composite reliability to measure internal consistency; the value must be > 0.6. The overall composite reliability measurement results were > 0.6, indicating that the data were consistent and able to explain the model (Table 3). This means that the data had been consistent and able to explain the model.

Construct validity was based on the average variance extracted (AVE). In this study, the AVE value of each construct was above 0.5; therefore, there was no convergent validity problem in the tested model. The entire model was deemed valid.

Inner model analysis

The results of the calculation in this study showed a goodness-of-fit (GoF) value of 0.68, which far exceeded the threshold of the large category. This indicated that the research model used had an excellent level of suitability and was feasible to implement. Thus, the model could not only adequately explain the relationships between variables but also comprehensively represent the phenomenon being studied. This high GoF value confirmed that the integration of constructs such as external support, farmer capacity, socio-entrepreneurship, and sustainability of soil fertility practices in the framework of the model could be trusted to provide a valid and reliable picture related to the dynamics of empowering coffee farmers to maintain soil fertility practices.

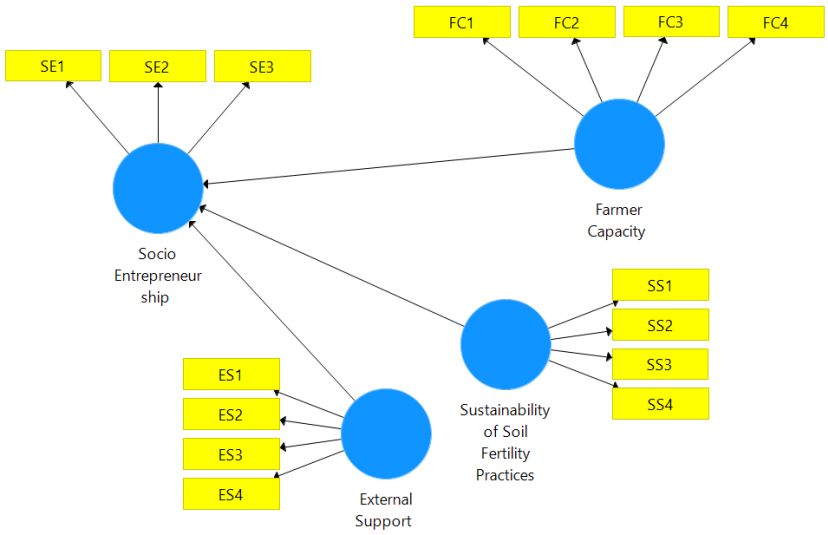

Figure 2. PLS-SEM final model

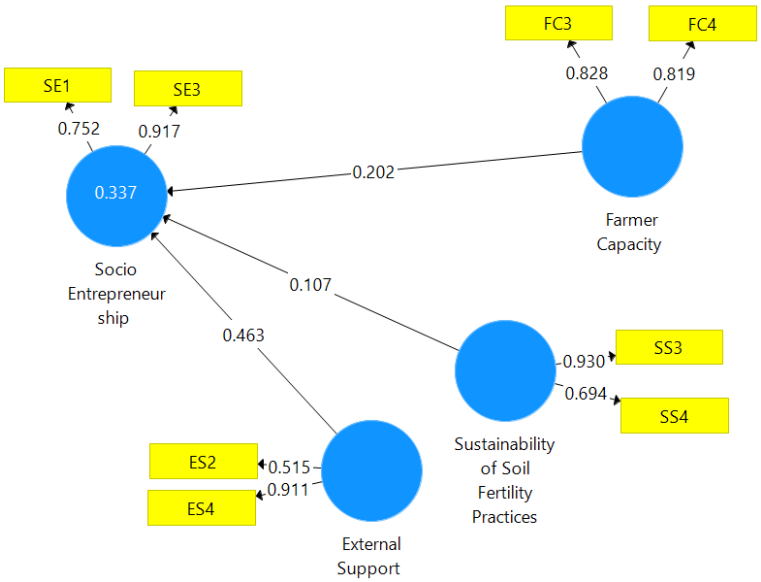

Figure 3. Loading factor values in the model

Table 3. Validity and reliability

	Composite Reliability	Information	Average Variance Extracted (AVE)	Information
External Support	0.7	Reliable	0.5	Valid
Farmer Capacity	0.8	Reliable	0.7	Valid
Socio Entrepreneurship	0.8	Reliable	0.7	Valid
Sustainability of Soil Fertility Practices	0.8	Reliable	07	Valid

Hypothesis test

The results of the hypothesis test showed that *external support* had a positive and significant effect on *socio-entrepreneurship*, with a coefficient value of 0.46, a T-statistic of 5.11, and a p-value of 0.00. This confirms that external support from the government, supporting institutions, and market access plays a very important role in encouraging the formation of social entrepreneurial activities among coffee farmers. Farmer capacity was also proven to have a positive effect on socio-entrepreneurship with a coefficient of 0.20, a T-statistic of 1.98, and a p-value of 0.05. Although the effect was smaller than *that of external support*, these findings suggest that farmers' knowledge, skills, and experience remain important factors in improving their ability to participate in social entrepreneurial activities. In contrast, the *sustainability variable of soil fertility practices* did not have a significant effect on *socio-entrepreneurship*, with a coefficient of 0.11, a T-statistic of 1.50, and a p-value of 0.13.

Table 4. Hypothesis testing

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics	P Values
External Support -> Socio Entrepreneurship	0.46	0.47	0.09	5.11	0.00
Farmer Capacity -> Socio Entrepreneurship	0.20	0.21	0.10	1.98	0.05
Sustainability of Soil Fertility Practices -> Socio Entrepreneurship	0.11	0.12	0.07	1.50	0.13

Description: P-value<0.05 =significant

A causal loop diagram of socio entrepreneurship empowerment model for coffee farmers in maintaining soil fertility practices

A causal loop diagram showing the relationship between *farmer socio-entrepreneurship* and *other factors* in the coffee farming system is depicted in Figure 4. The model comprised three reinforcing loops. The first loop (R1) shows

how better socio-entrepreneurship among farmers is linked to more job opportunities for young people. The second loop (R2) captures the correlation between enhanced farmer socio-entrepreneurship and farmer capability. The third loop (R3) depicts the correlation between enhanced farmer socio-entrepreneurship and sustainable soil fertility techniques. The three reinforcing loops describe the presence of a reinforcing link within the system shown in the model.

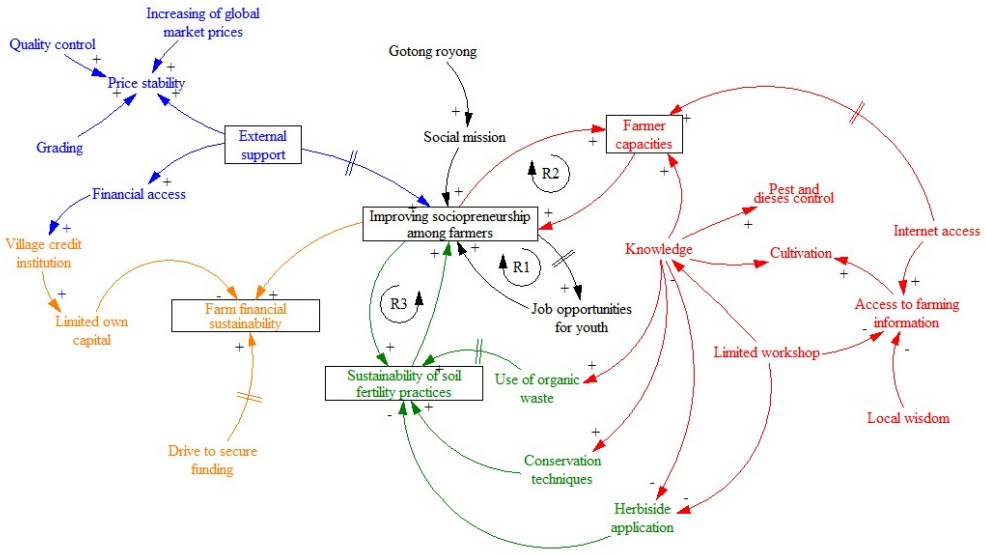

Figure 4. Causal loop diagram (model)

Discussion

External support had a significant influence on the socio-entrepreneurship development of coffee farmers in maintaining soil fertility practices in Rejang Lebong Regency

The results indicated that *external support* significantly influenced *the socio-entrepreneurial* development of coffee farmers by affecting their ability to maintain soil fertility practices. Specifically, access to capital and financing, as well as the stability of coffee prices in the market, served as primary forms of external support that enabled farmers to invest in and sustain these practices.

At the local level, Rejang Lebong coffee farmers face limited capital for soil conservation practices, such as the use of organic fertilizers, environmentally friendly pest control, and land rehabilitation. Access to financing from

institutions, cooperatives, and government programs can lower these barriers. It also enables farmers to invest in sustainable soil fertility. Farmers' easiest funding source is coffee mills. However, this system is familial and lacks rigid record-keeping, which may have hindered transparency and accountability. This potentially affects farmers' ability to secure further investments and manage finances effectively. The Zogning study (2023) confirmed that financial inclusion is vital for entrepreneurship by closing initial capital gaps for farming households. This aligns with asset-based financing models, which reportedly increased smallholder profits by up to 33% through access to capital and training (Zogning, 2023; One Acre Fund, 2023).

In addition, stable coffee prices influence farmers' decisions to invest in soil fertility. Volatility in global coffee prices, driven by climate change and international markets, often makes farmers' incomes unstable. External support, such as minimum prices or long-term contracts, would provide farmers with a sense of security to implement soil fertility practices. Long-term contracts would provide farmers with a sense of security to implement soil fertility practices.

Thus, the sustainability of soil fertility in the Rejang Lebong Regency did not depend only on the capacity of farmers. It was greatly influenced by the quality of external support. Interventions such as inclusive access to financing, price stabilization mechanisms, and market facilitation will strengthen the position of coffee farmers. These measures help them develop social entrepreneurship while maintaining the productivity and sustainability of their land.

Farmer capacity had a significant influence on the development of socio-entrepreneurship of coffee farmers

The capacity of coffee farmers was critical in shaping socio-entrepreneurship. *Knowledge of sustainable practices, such as* soil conservation, eco-friendly inputs, and agroforestry, was essential. However, in the field, Rejang Lebong farmers mainly relied on hereditary methods without knowledge upgrades. For example, they lacked a detailed understanding of the risks of mixing fertilizers with poisons or how to care for soil and use organic fertilizers. These practices threatened soil fertility. Research in Mexico found that the systematic management of traditional knowledge can promote environmental and economic sustainability in the coffee chain (Contreras-Medina *et al*., 2024). Additionally, farmer-led innovations that combine local insights with entrepreneurship strengthen agricultural resilience and diversification (Barman, 2025). Given this, extension worker involvement is needed for coffee farming in Rejang Lebong.

Additionally, access to agricultural information, such as through digital media, extension, and agronomic networks, broadens farmers' perspectives on new business opportunities. Building on this, Luo *et al*. (2024) state that farmers, especially those who are new to farming, utilize social networks to access capital and technological information, which increases entrepreneurial readiness (Luo, 2024). In line with these findings, tertiary research also notes digital skills and ICT tools as factors that strengthen entrepreneurial capacity. This suggests that digital skills accelerate access to information and technical support in remote villages (Chandio *et al*., 2023). Furthermore, the results in the field showed that farmers were very active on social media, such as Facebook, and had a high level of competence in using it. In addition, the internet network in the research location was adequate and did not become an obstacle for them to obtain information.

A socio-entrepreneurship empowerment model for coffee farmers to sustain soil fertility practices

Three conditions supported empowering coffee farmers to maintain soil fertility practices. First, as indicated by loop R1, socio-entrepreneurship leaded to new job opportunities for rural youth by increasing labor demand and enabling ownership of micro-, small-, and medium-sized enterprises (MSMEs). This labor demand arises from business diversification into value-added processing, digital marketing, and agro-tourism, which encourages youth involvement. Therefore, focusing empowerment on youth can specifically improve their modern business skills, which further strengthens soil fertility practices through their active participation.

Second, loop R2 emphasized that increasing social entrepreneurship directly strengthens coffee farmers' capacity by facilitating their access to information, training, and cultivation innovations. This access led to improvements in technical and managerial skills among fellow farmers (entrepreneur in agriculture), which, as Kademani *et al.* (2023) noted, plays a critical role in encouraging the adoption of sustainable agricultural practices. Furthermore, Wanzala and Njeru (2024) highlighted that improved access to financing and technical training facilitated by these networks drives increased coffee productivity. Therefore, implementing a targeted empowerment model through farmer groups for the common good is considered a more effective way to increase the capacity of coffee farmers.

Third, as indicated by the R3 loop, improving social welfare leads to more sustainable soil fertility practices because farmers, motivated by social entrepreneurship, are encouraged to use organic fertilizers, conservation

technologies, and agricultural waste management. By adopting these methods, they pursue both social and environmental missions. This causal link is supported by Selvanarayanan *et al*. (2024), who emphasized that technology-based innovation and environmentally friendly practices in coffee plantations can directly improve soil health. Similarly, Wright (2024) stated that regenerative coffee not only enhances productivity but also maintains the ecosystem. Therefore, social entrepreneurship acts as a catalyst by connecting economic goals with ecological outcomes, such as reduced mortality. As a result, the empowerment model could be designed to improve land conditions and promote soil-friendly cultivation practices, both of which are essential for increasing agricultural productivity and ensuring farming methods that support the economy and the environment.

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Conflicts of interest

The authors declare no conflicts of interest.

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