

Knowledge and adaptation strategies of coffee smallholders toward climate change: evidence from Tanjung Agung, Semende Darat Ulu

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ABSTRACT

Coffee farming was highly vulnerable to the impacts of climate change. Exploring the strategies used by small farmers in Tanjung Agung Village has had a big impact on climate change. This study aimed to identify the level of knowledge, adaptation practices, and polyculture practices and types of shade trees used by coffee smallholders in facing climate change in Tanjung Agung Village, Semende Darat Ulu Regency. These strategies have made a significant difference. This study used a qualitative, survey-based approach. It also conducted data collection and analysis. This process was both simultaneous and cyclical coffee smallholders have noticed the effects of climate change in the last 1-2 years. Also, 35% of smallholders have known about climate change for the last 3-5 years. Coffee smallholders use indicators to predict climate change. These indicators include increased temperatures and shifts in the rainy and dry seasons. Water availability was also an indicator. Up to 90% of small farmers take steps to reduce climate change. These steps include using better types of coffee, planting trees for shade, and controlling how far apart the coffee plants were. Farmers also make air holes and use coffee bean skins to improve the soil. Our findings show that coffee smallholders understand climate change impacts well. They also quickly use strategies to adapt their crops to the changing climate. Smallholders use 16 types of shade crops as a strategy. The most widely used shade crops were petai, mango, avocado and durian.

Keywords: agroforestry, adaptation, coffee smallholders, climate change, coffee canephora

INTRODUCTION

Climate change was a long-term alteration in the distribution of Earth's temperatures and weather patterns, primarily attributed to human activities, as conceptualized by recent theoretical frameworks (Mubangizi et al., 2025), where the process is very complex with a long duration and impacts that are difficult to anticipate properly and have a significant impact on the environment, social, and economy (Heri, 2023) the same thing was stated by (Setiawan et al., 2024) which will have an impact on the potential threat to the sustainability of coffee production (Eresanya et

al., 2021). The context of coffee-based deforestation is recognized to be able to carry out climate change mitigation and biodiversity conservation efforts to support livelihoods (Jawo et al., 2023).

Coffee production in South Sumatra, including Muara Enim and Semende, produced 212.4 thousand tons of coffee, which is 26.72% of the total national coffee production In 2022 (BPS, Muara Enim Regency in Figures 2025). According to records from the Directorate General of Plantations (2025), South Sumatra is the province with the highest coffee production in Indonesia, reaching 191,081 tons of dry coffee

beans in 2021, equivalent to 22 percent of total national coffee production. Various regions in South Sumatra, such as Semendo (Muara Enim), Muara Enim, especially Semende, are producers of superior Robusta coffee in Indonesia. Semende's Robusta coffee production is still considered fluctuating, despite its position as the leading coffee center in Muara Enim. One of the causes of this fluctuating coffee price is climate change in Tanjung Village. This change is closely related to global warming that has occurred in recent decades. Global warming is caused by rising global temperatures due to the greenhouse effect (Rahmat et al., 2019).

The phenomenon of climate change causes uncertainty in seasons and rainfall. This has a significant impact on the agricultural sector, particularly coffee crops. Coffee is vulnerable to climate change. Climate change can affect coffee production and, consequently, the quality and price of coffee itself. Climate change can put pressure on coffee smallholders, which is related to the economic marginality of farming households (Widayat & Baihaqi, 2015). Coffee smallholders in Indonesia is the most vulnerable to climate change (Holland et al., 2017), so adaptation strategies to climate change are very urgent in every policy formulation and resource utilization (Wakuma & Desalegn, 2019).

Efforts to increase coffee productivity as a result of climate change require adaptation efforts by coffee smallholders in the form of real practices in cultivation activities through knowledge, attitudes and skills that are smallholders behavior in cultivating coffee that must be maximized. Based on the statement above, The objective of this research was to identify the level of knowledge, adaptation practices, and polyculture practices and types of shade trees used by coffee smallholders in facing climate change in Tanjung Agung Village, Semende Darat Ulu Regency.

MATERIALS AND METHODS

Location

The research was conducted in Tanjung Agung Village, Semende Darat Ulu District, Muara Enim Regency, South Sumatra, with the coordinates of Tanjung Agung 4°43'39"S and 103°18'21"E. The research was conducted purposively for several

reasons: Tanjung Agung, or Semende in general, was a coffee center with the Semende coffee brand.

Tanjung Agung Village was also situated in close proximity to both a protected forest (HL) and a community-managed forest area, where coffee had continued to be cultivated in combination with various other perennial and seasonal crops. The research had been carried out from January to May 2024, during which period field observations, interviews with farmers, and ecological assessments were conducted to obtain a comprehensive understanding of local agroforestry practices and landscape interactions (Figure 1).

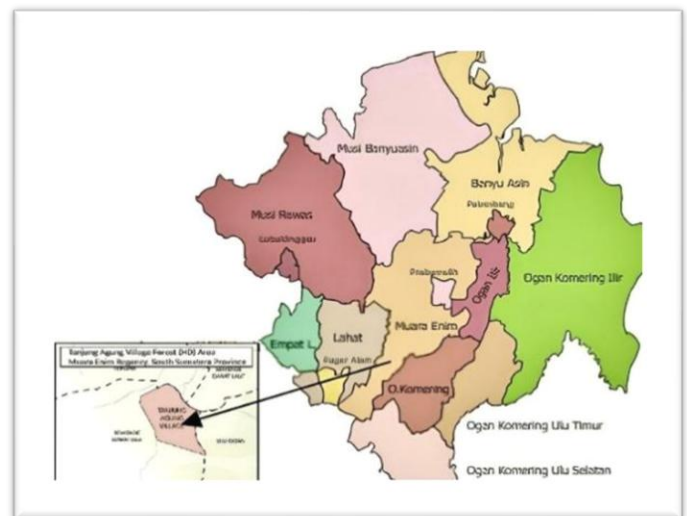


Figure 1. Research location

Research Procedure

This study employed a qualitative research approach and survey methods. The qualitative approach was used to provide a detailed and in-depth overview of the challenges smallholders face in response to climate change in Tanjung Agung Village. The characteristics of qualitative research were the process of collecting and analyzing data in the form of words (spoken or written) and human actions and behavior (coffee smallholders) and do not attempt to quantify them into data or numbers (Afrizal, 2015), because quantitative data could provide a clear picture of the research (Undari, 2024).

Data Source

Data collection and research respondents The data used in this study consists of primary and

secondary data. Primary data was data obtained directly from sources without the intermediary of a third party or other parties. Primary data collection included interviews, field observations, and questionnaires distributed to respondents (Laia et al., 2022). Primary data in this study were collected through a survey of coffee smallholders, interviews with key informants, and field observations. Secondary data sources could be derived from books, reports, research results, and other sources relevant to the research topic. The study respondents were 80 coffee smallholders households. The collection method used interviews with questionnaires for respondents and an interview guide.

Data Analysis Techniques

This study employed qualitative research, which conducted analysis continuously throughout the study. Data collection and analysis were conducted simultaneously and cyclically. This study employed interactive data analysis, encompassing data reduction, data display, conclusion drawing, and verification.

RESULTS

Smallholders Knowledge of Climate Change

Smallholders' knowledge of climate change was a fundamental aspect in mitigating and adapting to it. Coffee smallholders who had a good understanding of climate change would strive to adapt in order to minimize its impact on their coffee farming. However, coffee farms located in hilly or mountainous areas with relatively good protective vegetation offered advantages in terms of temperature and water availability.

Coffee plants, a plantation commodity (annual crop), tended to be drought-resistant. Coffee plants had a productive lifespan of 5–20 years. These plants had strong roots that were resistant to climate change, especially in terms of water availability, and were relatively tolerant of drought. Although they were relatively resistant to drought and limited water availability, they still experienced stress under prolonged dry conditions. Climate change, particularly drought due to the uncertain dry and rainy seasons, had a

serious impact on coffee productivity. An unpredictable rainy season caused coffee plant flowers to fall off, which in turn caused the coffee cherries to drop and rot, resulting in low coffee productivity. Climate change had a serious impact on coffee production. The level of knowledge about climate change among coffee smallholders in Tanjung Agung Village was shown in Table 1 of the smallholders' knowledge survey on climate change. The following survey was conducted regarding smallholders knowledge of climate change, as shown in Table 2.

Table 1. Smallholders general knowledge of climate change

Statement	Answer	Percentage (%)
Smallholders have a general understanding of climate change	yes	100%
	no	0%
The duration felt when climate change occurs	don't know	15%
	1-2 year	50%
	3-5 year	35%
	>5 year	0%
Sources of information on climate change and mitigation	I don't know	35%
	Internet	20%
	Official	25%
	Government	5%
	etc	15%

Table 2. Smallholders advanced knowledge of climate change

Statement	Answer	Percentage (%)
Perceived Climate Change	Changes in rainfall	65%
	Increased temperature changes	35%
Climate change causes an increase in pest and disease attacks	yes	20%
	no	80%
Climate change causes a decrease in production (crop yields)	yes	100%

Impact of Climate Change

Climate change was a change in temperature conditions and weather patterns over a relatively long period of time (Silfia & Sudarti, 2022). One aspect was changes in wind patterns worldwide. This occurred in the pattern and intensity of climate elements over comparable time periods

(Sumampouw, 2019). Furthermore, climate change was a real threat to human life and civilization (Luthfia, 2019). It was predicted that coffee production and the livelihoods of millions of smallholders would be severely impacted (Jawo et al., 2023). This long-term impact would result in several consequences that smallholders would experience. This climate change could have threatened the livelihoods of coffee smallholders in Tanjung Agung Village. Interviews using a questionnaire were conducted with 40 coffee smallholders in Tanjung Agung Village, Semende Darat Ulu District, regarding the impacts they perceived due to climate change (Table 3).

Table 3. Impacts Perceived by Smallholders on Climate Change

Statement	Answer	Percentage (%)
The impact of climate change on coffee farming	Don't know	15%
	Decrease in crop yields	
	a. <10 %	5%
	b. 10-50%	65%
	c. >50%	5%
	No impact	10%

Smallholders Adaptation to Climate Change

Humans made every effort to adapt in order to address new challenges they faced, particularly climate and environmental issues that significantly impacted smallholders. Therefore, smallholders had to adapt to address climate and environmental issues. Smallholders' adaptation was closely linked to the processes and systems they employed to sustainably mitigate the negative impacts of past, current, and future climate change. Smallholders could adapt to natural and climate change in planned or unplanned ways, depending on the challenges they faced. Smallholders' adaptation to climate change was influenced by several factors that impacted human-to-human interactions and interactions with the environment, including economic, social, political, cultural, ecological, and institutional factors (Nabila, 2019).

Tanjung Agung smallholders were adapting to climate change by leveraging their adaptive capacity, economic capacity, skills, family resources, and institutional support for effective

adaptation strategies. One of the key factors that influenced smallholders' ability to adapt to climate change was their adaptive capacity. Adaptive capacity referred to the ability of smallholders to adapt to changes in response to natural or climatic demands (Table 4).

Table 4. Adaptation efforts and knowledge regarding mitigation

Statement	Answer	Percentage (%)
Adaptation efforts made	Don't know	10%
	know, but not effort	20%
	Know and effort	70%
Smallholders were aware of mitigation (emission reduction)	yes	10%
	no	90%

Using Polyculture Practices

The term "mitigation" was still unfamiliar to local smallholders, especially coffee smallholders in Tanjung Agung Village. The percentage of smallholders who implemented climate change mitigation practices was still low (10%), but they were already doing so without realizing it. However, they did not realize that their actions were part of climate change mitigation efforts. Some smallholders used rain-tolerant coffee varieties to prevent the flowers from falling off. Beyond varietal considerations, the mixed coffee plantation system, in which smallholders planted shade trees in addition to coffee plants, was practiced by almost all coffee smallholders. Coffee plantations with shade trees were referred to as mixed coffee plantations. The mixed coffee plantations developed by coffee smallholders in Tanjung Agung Village generally combined coffee with several trees that had multiple benefits. The shade trees planted were tailored to the smallholders' needs and preferences. Some smallholders used shade trees that produced fruit for harvesting. Others planted woody shade trees to use their leaves for livestock feed. The types of shade trees on coffee plants could be grouped into multi-purpose tree species (MPTS), where these plants had multiple benefits, namely serving as shade trees for coffee from excessive rain or heat, producing fruit, producing wood, providing animal feed, and fertilizing the soil in coffee plantation areas.

Table 5. Planted protective plants

Name Protector Tree	Latin name	Number of Adopters
Angsana	<i>Pterocarpus indicus</i>	2
Lamtoro	<i>Leucaena leucocephala</i>	2
Mango	<i>Mangifera Sp.</i>	4
Banana	<i>Musa paradisiaca</i>	2
Medang	<i>Phoebe angustifolia</i>	3
Petai	<i>Parkia speciosa</i>	4
Lamtoro	<i>Leucaena leucocephala</i>	2
Jackfruit	<i>Artocarpus heterophyllus</i>	1
Duku	<i>Lansium domesticum Corr</i>	2
Mangosteen	<i>Garcinia mangostana L.</i>	2
Sun hemp	<i>Crotalaria anagyroides</i>	2
Acacia		
Seedlings	<i>Acacia villosa</i>	2
Mahogany	<i>Swietenia mahagoni</i>	3
Avocado	<i>Persea americana</i>	4
Candlenut	<i>Aleurites moluccanus</i>	1
Durian	<i>Durio zibethinus</i>	4

Based on their benefits, shade trees planted by coffee smallholders in Tanjung Agung Village were divided into two types: legume and non-legume shade trees. Legume shade trees had root nodules that produced nitrogen, which impacted soil fertility. Therefore, many smallholders planted legume shade trees. However, many smallholders also chose non-legume shade trees to obtain benefits, particularly fruit or wood with high economic value. The types of shade trees planted on coffee plantations were shown in Table 5.

DISCUSSION

The study showed that all respondents, all of whom were coffee smallholders, had a general understanding of climate change. According to the Intergovernmental Panel on Climate Change (IPCC), climate change refers to long-term shifts in temperature and weather patterns driven by natural processes or human activities (IPCC, 2021). Climate change was a phenomenon understood by coffee smallholders in Tanjung Agung Village, Semende Darat Ulu District, Muara Enim Regency. Respondents showed variations in how they perceived the length of time climate change had occurred. Half of the coffee smallholders stated that they did not know precisely when climate change began. Another 50 percent reported that they had sensed its impacts within the previous 1–2 years, while 35 percent indicated that the changes had been noticeable over the last 3–5 years. No respondents mentioned

experiencing climate change for more than 5 years. The signs most commonly relied upon by smallholders to recognize climate change had included rising air temperatures, shifts in the onset and duration of the rainy and dry seasons, and changes in water availability. (Jawo et al., 2023; Mbwambo et al., 2021; Abid et al., 2016).

In relation to the sources from which respondents had obtained information about climate change and mitigation, their answers were diverse. A total of 35 percent stated that they had not known the origin of the information. Meanwhile, 20 percent reported that they had accessed such information through the internet, and 25 percent indicated that it had been provided by local extension officers. Only 5 percent mentioned that the information had come from government institutions, whereas the remaining 15 percent explained that they had received it from other sources, such as family members, their children, or through their own personal experiences. On average, smallholders also explained that they experienced climate change themselves, where there were quite extreme changes in air temperature and water availability for their plantation land (Barrett et al., 2025).

The questionnaire results in Table 2 indicated that climate change had exerted negative effects on coffee farming practices. Smallholders reported increased pest and disease disturbances along with reduced production levels. Most respondents (65%) recognized climate change through alterations in rainfall behavior, particularly the shifting boundaries of the rainy and dry seasons. Meanwhile, 35 percent reported awareness of more extreme climatic conditions, including rising air temperatures. They noted that the once-cool air in Tanjung Agung had become noticeably warmer over time, reflecting a heightened awareness of climate-related changes in recent years. Evidence of climate change was also reflected in the reported increase in pest and disease incidence on coffee plants, although this rise was not considered substantial (Koutouleas et al., 2025). Only 20 percent of smallholders experienced a noticeable increase, whereas the remaining 80 percent stated that the impact on pest and disease levels had been minimal. Climate change is actively negatively impacting coffee production, causing a 10-50% decline in

production. Sixty-five percent of respondents stated that climate change has significantly reduced coffee production. When coffee plants flower, heavy rainfall causes flowers to fall off and young fruit to rot. In recent years, erratic rainfall has also led to a decline in production. This phenomenon can also exacerbate pest and disease attacks on coffee plants, which can reduce the quality and quantity of the harvest. Pest and disease attacks on coffee plants can reduce the quality and quantity of the harvest, as mentioned in journals discussing coffee pests and diseases. One pest that damages coffee cherries is the coffee berry borer (*Hypothenemus hampei*).

Smallholders' adaptive capacity, which is the ability to adapt to climate change, is influenced by their knowledge, asset ownership, access to technology, government policies, institutional stability, and their perceptions of climate change. Smallholders' perceptions and knowledge of climate change are key factors influencing adaptive capacity in climate change adaptation strategies. All of respondents, only 70% of smallholders knew about the adaptations carried out and they made efforts to make these adaptations. The remaining 10% of smallholders did not know what adaptation efforts should be made and as many as 20% knew but did not make efforts to adapt. Efforts made by coffee smallholders in Tanjung Agung Village include the use of superior seeds, planting and rejuvenating coffee with superior planting materials, planting shade plants, using organic fertilizers, making reservoirs, irrigation and drainage systems. This is referred to as CSA (Climate Smart Agriculture) practices (Djufry, et al., 2022). Correspondent regarding the knowledge of smallholders who know and understand about mitigation, the number of smallholders who mitigate against climate change is low, namely 10%, but in reality almost all smallholders have made these mitigation efforts but they do not realize that the efforts made are part of mitigation against climate change. Several mitigation-oriented farming practices had been applied by smallholders, although they had not yet recognized these actions as part of climate-change mitigation efforts. Among the practices observed were the incorporation of shade trees within coffee plots (Ehrenbergerová et al., 2021), the use of

standardized spacing for Robusta coffee planting (Ehrenbergerová et al., 2021), the construction of moisture-conserving aeration pits (Kobusinge et al., 2023), and the conversion of coffee pulp into biochar to improve soil nutrient content and moisture retention (Sánchez-Reinoso et al., 2023).

Table 5 indicates that coffee smallholders had cultivated 16 different shade-tree species alongside their coffee plants. Mango (*Mangifera* sp.), petai (*Parkia speciosa*), avocado (*Persea americana*), and durian (*Durio zibethinus*) emerged as the most frequently planted shade trees, with 40% of respondents reporting the same species. Petai, avocado, and durian had generally been selected because they produced fruit with considerable economic value. In addition, mahogany (*Swietenia mahagoni*) and medang (*Phoebe angustifolia*) had been chosen by 35% of respondents as shade trees. Smallholders preferred these woody species because their high-quality timber could later be used for building houses or small field shelters. The intercropping of woody shade trees with other crops had also been practiced to provide regulated shading for understory plants, which contributed to ecological stability and diversified smallholders' sources of income within coffee agroforestry systems (Sari et al., 2023; Salamanca et al., 2025). The combination of various plant species had enabled them to complement one another both temporally and spatially. The vegetation cultivated by smallholders had consisted of woody species, food crops, and understory plants. These components had fulfilled different ecological roles, with tall woody trees functioning as shade providers that reduced direct solar exposure, while low-canopy plants had served as ground cover to enhance soil fertility and minimize erosion.

CONCLUSION

Coffee smallholders in Tanjung Agung Village are aware of climate change in their village. Fifty percent of coffee smallholders are aware that climate change has been felt for the past 1-2 years, while 35% are aware that climate change has been felt for the past 3-5 years, and none responded that it has been felt for more than 5 years. The indicators most commonly used by coffee smallholders to predict climate change include

increasing temperatures, shifts in the rainy and dry seasons, and water availability. Sebanyak 90% of smallholders mitigate climate change to protect their coffee farming businesses. Climate change mitigation practices carried out by coffee smallholders include the use of superior coffee varieties, planting shade trees, regulating coffee plant spacing, creating ventilation holes, and utilizing leftover coffee husks to increase soil fertility and moisture. There are 16 types of shade trees planted by smallholders, including Petai (*Parkia speciosa*), Mango (*Mangifera Sp*), Avocado (*Persea americana*), and Durian (*Durio zibethinus*) are the most commonly planted shade trees on coffee plantations with 40% of the total respondents. These shade trees were chosen because they produce fruit that they can consume and trade.

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