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Article

Coffee farmers' knowledge construction about climate change

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Abstract: Climate change plays a vital role in shaping the knowledge construction of farmers for managing their agricultural land. Therefore, this study aims to analyze the coffee farmers' knowledge construction process regarding climate change. This research utilizes qualitative methods. This research approach uses the grounded theory, which can help researchers uncover the relationship between the coffee farmers' knowledge construction and climate change. The data were collected through semi-structured interviews and analyzed using constant comparative methods. The transcription of the field notes was analyzed using NVivo version 12, a program for analyzing qualitative data. There were 33 informants in the study. This study found that the conditions and situations of wind speed and uncertain whether strongly influence the farmers' construction of climate knowledge. Coffee farmers are looking for new ways to respond to climate change, such as increasing the intensity of the care they give to their coffee plants, gradually harvesting according to the ripeness of the coffee fruits, finding alternative ways to dry the coffee beans, and reducing the use of fertilizer. However, coffee farmers are also starting to adapt old knowledge from their parents to the latest perceived climate phenomena, so that they can look for alternative sources of livelihood outside their farms. This knowledge construction process serves as a form of adaptation by the coffee farmers to climate change, and reflects the dynamic between traditional knowledge and current experience. Understanding this knowledge construction helps coffee farmers to cope with climate change and to design appropriate policy strategies to support the sustainability of coffee farming in an era of climate change. Further research is needed at the regional level.

Keywords: knowledge construction; climate change; coffee farmer

1. Introduction

Climate change has an impact causing droughts, strong winds, and the emergence of new pests, all of which can lead to decreasing agricultural productivity. The effects of these changes have a severe impact on farmers' livelihoods. Farmers try to adapt to the conditions they experience, based on what they learn from their environment. This case shows that local communities can learn from their environment and solve problems, including climate change and resource problems (Rahn et al., 2014; Kumari et al., 2020; Akpan and Zikos, 2023; etc.).

Indonesia's coffee farming community is among the most vulnerable to climate change. Coffee plants are the plants that are most affected by climate change. Time uncertainty, rainfall distribution, and the development of coffee fruit borer pests make it difficult for farmers to determine the correct management choices on their agricultural land (Ademe et al., 2020; Dufour et al., 2019; Holland et al., 2017; etc.).

The Kahayya coffee farming community, as the largest coffee producer in Bulukumba Regency, South Sulawesi, is directly affected by climate change. Millions

of coffee farmers in Indonesia, including the Kahayya coffee farmers, suffer losses due to decreased productivity. It is crucial to identify the impact of environmental changes around them and how the farmers construct their knowledge about climate change. Adaptation strategies, based on the construction of the coffee farmers' knowledge about climate change, need to be developed systematically and be based on scientific procedures so that they are more useful in policy discussions and for developing coffee farming communities. (Berrang-Ford et al., 2019; Mbaye et al., 2023).

How good is the learning process of the Kahayya coffee farming community in the face of climate change? The article also highlights how coffee farmers understand the complex environment and climate change. Based on these problems, this analysis can help compile the construction of the farmers' knowledge about climate change, to compile the problems faced when farming, the basics of understanding climate change, and the knowledge inheritance system they practice. Also, the long learning process for understanding climate change and its effects on coffee farming. Other research also highlights the importance of understanding the social, political, and economic processes that contribute to the construction of societal risks and vulnerabilities (Montejo-Damián et al., 2022; Sarathchandra et al., 2022).

Previous studies have yet to examine how farmers construct knowledge about climate change. Research into how farmers construct knowledge about climate change and what substance of knowledge they construct is vital, because findings about it can be the basis for knowledge delivery to farmers, strengthening their capacity to adapt to the impacts of climate change.

This research places farmers' knowledge as something that is continually processed because, in principle, humans are creative creatures. Thus, constructing the farmers' knowledge of climate change is a learning process regarding their situation. This learning process is about how to respond to the changes around them, manage the chaos of their life experiences, find patterns for handling problems, find connections and dependencies, and make a myriad of daily choices for survival. The activeness of the individual in studying the changes around him/her makes or changes his/her actions in response to the situation. The learning process from the surrounding events forms habits and cognitive structures. This shows that the formation of individual or group mental structures is dynamic, caused by following the changes around them (Berger and Luckmann, 1967; Cunliffe, 2008; Sampean et al., 2019; Schudson and Gelman, 2023; Mamykina et al., 2015; Jones et al., 2011; Carlson and Schneickert, 2021; Ross et al., 2020).

Natural resources management (NRM) researchers found that attitudes, preferences, and stakeholder values construct knowledge about individuals or groups. The construction of knowledge of reality can reveal the hidden reality that occurs in society. However, it fails to consider humans' ability to predict outcomes or analyze cause-and-effect relationships in response to different events (Hornsey and Fielding, 2020; Berger and Luckmann, 1967; Sampean et al., 2019).

This approach was developed in psychology, which places the individual's mental model as a representation of external reality, in response to the events that occur. These internal models or representations are often generated and represented through concepts or cognitive mapping (Jones et al., 2011; Ross et al., 2020). A

cognitive map can be considered a graphic map that reflects mental processing, consisting of collected information and a series of cognitive abstractions of individuals when filtering, coding, storing, correcting, and remembering information about physical phenomena and experiences into external representations (Vanwindekens et al., 2013; Vuillot et al., 2016; Levy et al., 2018; Lalani et al., 2021). Thus, according to Kropf et al. (2021) and Ross et al. (2020), mental models and cognitive maps (CMs) are used to study individuals or communities, internalize perceptions about specific problems or challenges, and make decisions about the various approaches used in previous research. The mental models, cognitive maps, and personal construct psychology are all principally constructs of the knowledge of reality. The construction of knowledge over fact emphasizes the causality involved in representing internal reality from external reality. This study's theory of knowledge construction on climate change looks at the dialectical relationship between the internal and external facts determining the understanding of Kahayya coffee farmers in responding to ongoing climate change (Berger and Luckmann, 1967).

This study aims to understand how coffee farmers construct knowledge about climate change, the substance of the knowledge they construct, and the form of action that is born from the construction of knowledge about the impacts of climate change. After the introduction, this paper contains the research methods. It continues with a description of the substance of the knowledge constructed by farmers, the process of knowledge construction taken by farmers, and the actions taken by farmers based on their knowledge of dealing with the impacts of climate change. The final section contains the conclusions, research limitations, and suggestions for further research.

2. Literature review

Research into adaptation strategies and farmers' perceptions of the environment has been conducted using various approaches. Researchers have focused on climate change risk assessments, adaptation strategies, the farmers' level of vulnerability, representations of climate change and adaptation strategies, and the importance of appropriate policies within an institutional framework. Ranasinghe et al. (2023) examined the adaptive capacity of farmers influenced by socioeconomic characteristics and resource availability. Adaptive capacity is also influenced by government policies that support the fulfillment of the needs of vulnerable groups for household resilience (File and Derbile, 2020; Mbaye et al., 2023).

Different findings from Jabik (2023) show that adaptive capacity depends on the knowledge formed in the community. Knowledge about climate change that is obtained from local ecology allows them equal access to natural resources, sustainable resource management, disaster risk reduction, and socially solid organizations (Ullah et al., 2022). Based on these previous research results, it was found that the relationship between the environment and the community influences farmers' adaptability. Government policies can increase the resilience of fishing communities, community institutions, and cultural embeddedness or traditions that affect farmers' knowledge. These aspects only focus on the structural elements that shape the construction of farmers' understanding of climate change. In contrast, this research places farmers' knowledge in a continuous process because humans are creative creatures (Berger and

Luckmann, 1967; Cunliffe, 2008; Sampean et al., 2019; Schudson and Gelman, 2023).

Farmers' knowledge construction on climate change is obtained through the process of learning about climate change that takes place around them, about how to organize the chaos of their life experiences, find patterns for handling problems, find connections and dependencies, and make a myriad of daily choices for survival (Mamykina et al., 2015). The individual's activeness in learning about the changes around him/her makes or changes his/her actions in response to the situation (Jones et al., 2011). The learning process of the surrounding events forms habits (habitus) and cognitive structures (Sieger et al., 2012; Carlson and Schneickert, 2021). Ross et al. (2020) show that the formation of individual or group mental structures is long-lasting (hysteresis), or dynamic, in the face of changes around them.

Hornsey and Fielding (2020) found that the attitudes, preferences, and values of stakeholders affect the construction of individual or group knowledge. Knowledge construction of reality can reveal hidden facts in society (Berger and Luckmann, 1966; Sampean et al., 2019). However, in principle, it fails to consider the human ability to predict outcomes or analyze cause-and-effect relationships in response to various events (Sampean et al., 2019) as a knowledge construction of reality. Knowledge construction of reality emphasizes the causality involved in representing the internal reality from the external (Berger and Luckmann, 1967).

This research takes a knowledge construction theory approach in exploring the reality faced by the coffee farming community in Kahayya Village. This research differs from previous studies that focused more on practical aspects, such as climate change risk assessments, adaptation strategies, the farmers' vulnerability levels, and policy implications. Instead, this research delves deeper, to understand how these coffee farmers' long-term knowledge and experiences are formed. This approach allowed the researchers to explore their perspectives, opening deep insights into how the coffee farming community is coping with climate change.

3. Methodology

This research utilizes qualitative methods to explore an in-depth understanding of the coffee farmers' activities. Qualitative methods allow researchers to understand social phenomena from the perspective of the people who experience them. In this case, it is about the context, processes, perceptions, and meanings experienced by coffee farmers. Based on this context, the researcher chose the grounded theory as one of the qualitative approaches to investigate critical issues about the coffee farmers' knowledge of climate change.

Grounded theory research is used to build a framework for thinking about the methods and processes of coffee farmers in building an understanding of climate change, and what steps the farmers have taken, and to what extent, in adapting to the impacts of climate change. Second, with this idea, we can build theories regarding the essential issues in people's lives (Glaser and Strauss, 1967; Glaser, 1978; Strauss and Corbin, 1998). In this study, the researchers tried to compile a list of the essential issues concerning climate change, based on the knowledge of coffee farmers. These critical issues arise from the stories they tell about the areas of interest they have in common with the researchers. Third, with this method, we try to unmask the

knowledge formed in society, because the data collected still needs a previously constructed idea to prove or disprove. Fourth, climate change studies, based on the knowledge construction of the local community, still need to be researched. According to Kosasih (2018), in this situation, the grounded theory is very relevant for understanding the formation and construction of knowledge among the coffee farmers in Kahayya Village. Thus, researchers would not bind themselves to concepts that have been built or developed related to the topic to be studied. Thus, the concept or thesis that will be built in the future relies on the data obtained in the field (Mills et al., 2006).

3.1. Research location and context

Kahayya Village is a village located in Kindang District, Bulukumba Regency, South Sulawesi. The village is located at the foot of Mount Bawakaraeng, directly adjacent to Sinjai Regency. Kahayya Village is the largest coffee-producing village in Kindang District, and even in Bulukumba Regency. Kahayya Village, according to the Central Bureau of Statistics, Bulukumba, in 2022, has the potential to have 500 hectares of land specifically for coffee plants with 25,000 trees. Elis further mentioned that in addition to land owned by the community, the community also utilizes forest areas in community forest (HKM) schemes that are managed by 122 farmers. The total coffee harvest in Kahayya Village is estimated to reach at least 300 tons per year. The research location can be seen in **Figure 1**.

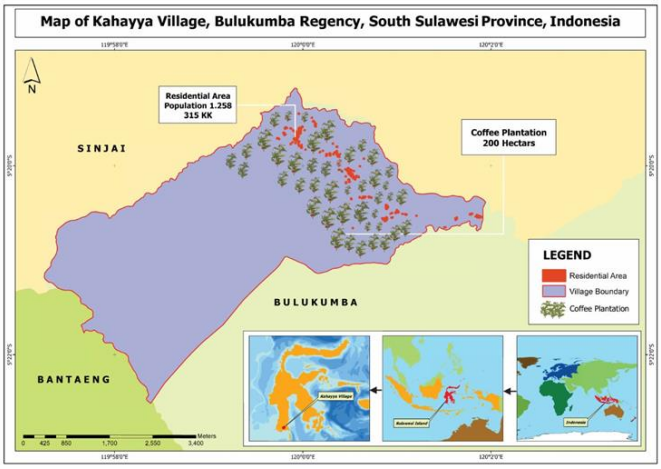

Figure 1. Map of research location and coffee plantation.

Kahayya Village has a tropical climate with two seasons: the dry season between July and December and the rainy season between January and June. The average temperature ranges from 10 ℃ to 24 ℃. The maximum temperature occurs from September to October, with temperatures reaching 30 ℃, and lows reaching 26 ℃. This average temperature is very suitable for the cultivation of coffee plants. Kahayya Village is located at an altitude of 700 to 1800 m above sea level, meaning coffee is the only plantation crop that can grow well. Cold temperatures and high sea-level topography are very suitable for coffee plants.

The area of the village community's coffee plantation in Kahayya is 200 ha. Kahayya Village also supports coffee production in Kindang District, which has a

population of 1143 people (BPS, 2023). All the heads of households work as farmers. Coffee is a mainstay commodity in this area. All the heads of families are divided into seven groups of coffee farmers. Each household has a minimum of 1 ha of land, some also have land of up to 5 ha. The entire land is planted with coffee. The distribution of the community coffee plantations can be seen in **Figure 1**. Based on these considerations, Kahayya Village was chosen as the research location.

3.2. Data collection techniques

This research was carried out in several stages. The first stage consisted of observation, interviews, transcription, and writing the research results. The data collection techniques used in this study included open interviews, structured interviews, and in-depth interviews. In the open interviews, informants were asked to answer questions sequentially according to the flow of their speech. However, by the end of the interview, the questions became more structured to ensure the data's consistency with the research objectives. In the next stage, the researchers probed deeper into certain pieces of information or cases, to explore the substance of knowledge construction owned by the coffee farmers. Following an in-depth interview approach, several informants were interviewed repeatedly to complete the related questions. While in the field, the researchers also made observations in a diary. This diary recorded essential statements, the atmosphere of the interview, the expression of the informant, and essential events while at the research site (Denzin and Lincoln, 2009; Leavy, 2017).

The face-to-face interviews allowed researchers to see the interviewees' facial expressions and body movements. However, in the triangulation process (validation and confirmation), the interviews were carried out by telephone, where expressions can be interpreted by the tone of voice. Before entering the main topic, an attempt was made to establish a comfortable relationship between the researcher and the interviewee. Maryudi and Fisher (2020) explain that situational management is critical in an interview. Before researchers conduct interviews, they try to create a relaxed atmosphere (breaking the ice) by building emotional connections with the interviewees through introductions, building friendships, and discussing things personally. After that, the researcher commits to conducting the interviews. The duration of each interview lasted between 50 min and 90 min. Recordings and interview notes were then transcribed in writing.

The primary informants in this research were coffee farmers and community leaders who have influence in Kahayya Village. The number of informants interviewed was 33. The coffee farmers were selected through snowball sampling, while community leaders were selected purposefully, based on information from the coffee farmers with whom they interact.

3.3. Data analysis techniques

This research used a grounded theoretical approach with a data analysis technique that used constant comparative methods (CCM). This data analysis technique is carried out by sorting and organizing raw data citations to compile attributes and categorize the data from interviews and research memos (Kolb, 2012; Lassig, 2022).

The grounded theory approach is a common methodology for systematic data collection that is applied using a series of methods to generate an inductive theory about a substantive area (Martin and Turner, 1986). As Glaser (1978) stated, ‘‘The goal of the grounded theory is to generate a theory that accounts for a pattern of behavior.”

There are several stages in the data analysis process using the grounded theory of data collection and transcription. Data analysis, using this approach, is a process that systematically reviews the qualitative information found in the files, in order to identify the core concepts or constructs and their relationships.

First is the encoding phase or “open coding.” The purpose of this is to identify the keywords from all the collected data. The transcripts are coded line by line and labeled into concepts.

Second, the concept formation phase or “axial coding,” with the aim of gathering codes with similar content, allowing the data to be grouped into related categories to form concepts. Relationships between the codes are sorted and established.

Third, the categorization phase or “selective coding,” with the goal of grouping the concepts formed, then selecting those related to the theory formation for the research problem (Corbin and Strauss, 1990). The grounded theory steps can be seen in **Table 1**.

Table 1. Grounded theory steps.

Coding steps	Explanation
Open coding	Categories of information should be constructed for the studied phenomenon. This stage can be defined as the division of the collected data by coding.
Axial coding	After open coding, the data should be grouped in new ways and presented in tables. In this step, the central phenomenon or the core concept of the study is defined. This stage involves data integration.
Selective coding	In this stage, first draw a figure and then attempt to write a narrative to better understand the problems by using a metaphor to illustrate the prevailing values. This links result with the findings in the literature.

Source: (Glaser, 1978).

Coding and categorizing qualitative data means employing clustering and classification schemes; linking categories to the concept and then forming a theory. For example, the category “wind speed” relates to the change of seasons (Maxwell and Miller, 2008). The data analysis steps can be seen in **Figure 2**.

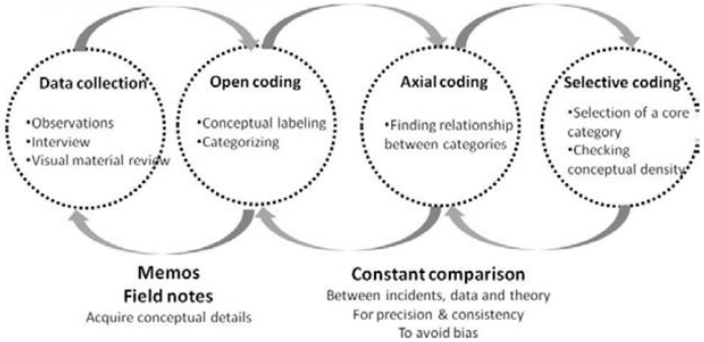

Figure 2. Step of data analysis.

4. Findings

The problem of climate change, at its core, is a socioeconomic and governance problem with asymmetric power systems, contradictory knowledge systems, and institutional fragmentation. This problem is an obstacle to society's adaptation to climate change. So, it is essential to understand the construction of the coffee farmers' knowledge of climate change. These knowledge constructs guide us to understand the complex situations facing coffee farmers. The construction of farmers' knowledge about values, norms, and culture can help stakeholders and scientists determine priority policies and strategies for mitigating and adapting to climate change. The construction of the farmers' knowledge can be seen from several dimensions, namely their substance of knowledge, the construction process, and knowledge networks. (This section will outline the research findings relating to the substance of knowledge about climate change that the farmers construct, how they construct that knowledge, and the actions taken by them as a consequence of their knowledge about climate change).

4.1. The substance of farmer-constructed knowledge on climate change

The substance of the coffee farmers' knowledge of climate change includes an understanding of the impacts of climate change on various aspects of the coffee farmers' lives, such as crop productivity, coffee bean quality, diseases and pests, and access to resources. This study looks at the changes in temperature, rainfall patterns, humidity, and weather extremes such as excessive rainfall, drought, floods, and heatwaves that can affect coffee production. The response of the coffee farmers to the situation and conditions faced can be seen in **Table 2**, which illustrates that most (97%) have more extended rainy periods and shorter dry periods, 82% think that they are currently experiencing strong winds, 12% have sunny weather in the mornings, but only briefly, then it gets cloudy, then rains, and only 6% mention temperature changes.

Table 2. Categories of substance knowledge about climate change constructed by farmers.

No.	Aspects of knowledge about climate change	Percentage of farmers (%)
1)	The wind is getting stronger	82
2)	Longer rainy periods and shorter dry periods	97
3)	The weather is sunny in the morning, but only for a short time, then it gets cloudy and then it rains	42

The substance of the farmers' knowledge guides the development of adaptation and mitigation strategies that can help communities deal with already inevitable climate change. The substance of a knowledge-oriented focus is on understanding the environmental situation perceived by farmers, and the use of such knowledge in agricultural systems.

4.2. The process of building coffee farmers' knowledge about climate change

The process of knowledge construction by coffee farmers about climate change refers to the efforts of coffee farmers to acquire new knowledge, or change the existing knowledge, to face the challenges arising from climate change. The process of knowledge construction can be seen in **Table 3**.

Table 3. Coffee farmers' knowledge construction process.

No.	Categories knowledge construction process	Percentage of farmers (%)
1)	Inheritance of knowledge from parents (inheritance)	78
2)	Formation of cognition through the process of learning from experience (experience)	45
3)	Through discussions among farmers	78
4)	Learn from the people in the village	27

Table 3 shows the knowledge construction process carried out by coffee farmers. About 78% of climate change knowledge is obtained from their parents' inheritance systems. This knowledge is passed on from generation to generation, allowing farmers to learn traditional practices that have proven effective for coffee's cultivation. Meanwhile, 45% revealed that their knowledge about the climate is obtained through the formation of cognition through learning from experience. They learn from every situation they face. These learning results are obtained to increase their knowledge and improve the quality and efficiency of their coffee farming practices.

Discussions with fellow farmers support this knowledge-construction process; about 78% of coffee farmers choose to share their experiences, knowledge, and techniques with other farmers in their communities. These discussions enable a collective exchange of ideas and learning, thus encouraging innovation and improvement in coffee farming practices. In addition, they learn from the leaders in the village, by as much as 27%. Coffee farmers say they learn from respected figures in their villages. These people often have a rich knowledge and vast experience of coffee cultivation. Farmers learn from them through direct interaction, observing their practices, and obtaining valuable advice that helps them develop their own farming knowledge.

The combination of this inheritance of traditional knowledge, learning through experience, discussions between farmers, and learning from leaders in the village contribute to increasing their knowledge and understanding of climate change. This construction process has been a long-lasting process in the farming community in Kahayya Village, as can be seen from various research findings described in the knowledge inheritance system, cognition formation, discussions among farmers, and learning from village leaders.

4.3. Social networks in coffee farmers' knowledge construction

The social networks of the coffee farmers contribute to the formation of their knowledge construction by building connections, sharing knowledge, strengthening solidarity, and strengthening the farmers' resilience. Social networks act as forums for exchanging information and for sharing coffee farmers' experiences of climate change. The social networks formed in constructing knowledge about climate can be seen in **Figure 3**.

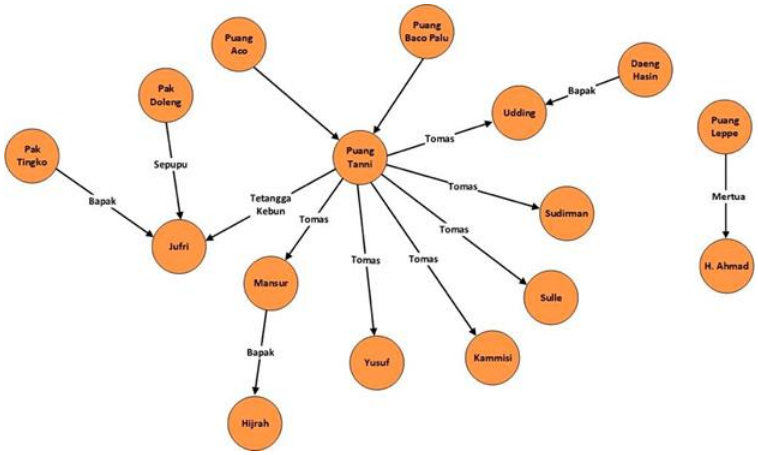

Figure 3. Social networks in the formation of knowledge about climate change.

4.4. Action consequences of constructed knowledge about climate change

The construction of coffee farmers' knowledge about climate change influences their behavior and actions. Coffee farmers' actions refer to their knowledge and understanding of climate change, which affects how they act and respond to the challenges faced. Farmers who have a strong understanding of the impacts of climate change have an adaptable tendency to adopt more sustainable and adaptive farming practices for the situations they face. The consequences of such knowledge about climate change are presented in **Table 4**.

Table 4. Actions from the construction of coffee farmers' knowledge about climate change.

No.	Action	Percentage of farmers (%)
1)	Waiting until the climate improves	12
2)	Coffee treatments are intensifying	30
3)	Harvesting is carried out gradually according to the ripeness of the coffee	39
4)	Making coffee drying alternatives	30
5)	Looking for alternative sources of livelihood	15
6)	Adapting old knowledge to the latest experiences	9
7)	Reduced fertilizer use	15

Table 4 provides an overview of the actions taken by coffee farmers, based on their construction of knowledge about climate change. In the table, some of the actions seen include waiting until the climate improves by 12%, carrying out

intensive coffee plant care by 12%, carrying out gradual harvesting according to maturity by 39%, finding alternative drying methods by 30%, looking for alternative livelihoods by 15%, adapting old knowledge to new experiences by 9%, and reducing fertilizer use by 15%. Coffee farmers' knowledge of climate change shapes their actions and behavior. Coffee farmers with a strong understanding of climate change and the importance of adaptation tend to adopt more sustainable and adaptive agricultural practices. They can change their planting patterns, improve crop care, optimize harvest times, and look for livelihood alternatives that are more resilient to climate change.

5. Discussion

5.1. The substance of farmer-constructed knowledge about climate change

5.1.1. Faster wind speeds

In the past, wind speed provided information for the planning of agricultural activities. The farmers observe the wind's speed, direction, pattern, and intensity. This information is used for land clearing activities, planting seedlings, and at harvest time. Information about strong winds is usually a sign of early rain and the end of the rainy season. This is stated by DMT farmers as follows:

> The seasonal changes in Kahayya Village are frequent rainy seasons accompanied by strong winds. It has been almost three years since the weather in Kahayya Village was mostly rainy compared to the dry season; sometimes, the weather was hot but very short (7 to 10 days) (DMT farmer, 41 years old).

DMT farmers assert that rain events and strong winds always characterize seasonal changes. This explanation is reinforced by the opinion of AHM farmers, who state that strong winds always occur yearly as a sign of the beginning of the rainy season, as explained below:

> Strong winds also occur, but solid winds every year will occur.... Signs of seasonal changes can be seen if there is lightning and strong winds during the rainy season, indicating that the rainy season will end.... Strong winds can be felt during the rainy season, and in the dry season, the wind is not so strong (AHM farmer, 61 years old).

The change of seasons is again confirmed by the explanation of ASR farmers, who state that the shift occurs earlier, usually in month one (January). Apart from this, strong winds have occurred in December, indicating a change in the rainy season. This condition makes it difficult for farmers to predict the climatic conditions they face. This condition is explained by ASR farmers, who say that:

> Strong winds normally occur on the first of January, or usually in the first month. But now they come in December. It means that month one is not 10 days old; the wind is already uncharacteristically strong, and do I know why it is like this? It is now 2023, we still need to find out what the season will be like. Strong winds are already difficult to predict (ASR farmer, 48 years old).

Seasonal shift events have occurred in recent years, including in December 2022, when strong winds came and lasted for 10 days. This explanation is offered by BHR farmers, who state that:

> Strong winds can cause the roof of the house to fly.... Strong winds are expected from January to March. However, in 2022, strong winds occurred in early December for almost 10 days (BHR farmer, 28 years old).

The strong winds that lasted for 10 days harmed residents and farmers. Many trees fell, even many clove and coffee plants fell, and branches were broken. This explanation is expressed by AMR farmers, who said:

> A strong wind began in month one and lasted approximately 10 days. Strong winds usually result in trees falling (AMR farmer, 40 years).

The trees fell this year because the strong winds were more powerful than those in the previous year, and the destructive power is more significant. This explanation was found from the interview of HJH farmers, who said:

> Strong winds will also occur every year, but for this year, strong winds occur very often, so that many trees fell.... Strong winds will occur every year between months one and three, but now strong winds come in month 12 (HJH farmer, 24 years old).

From the findings of the interviews, it can be concluded that strong winds mark the change of seasons, and this has now occurred earlier for several years. Strong winds indicate the onset of the rainy season. Changes in the wind's pattern and speed certainly affect the rainy and dry seasons. Strong winds have a very negative impact on plantation crops and can also change rainfall patterns, while plantation crop production depends on rain receipts (Prasada Rao, 2016).

5.1.2. The rainy period is getting longer, and the dry period is getting shorter

One of the characteristics of the transition of the seasons between the dry and rainy season is the arrival of monsoons (strong winds). The transition is significant for farmers in preparing their land. Land rotation is a type of indigenous knowledge that has been transmitted from generation to generation (Mappa et al., 2018). For coffee plants, the transition period is beneficial for fertilization because the coffee plants flower at that time. In this period, the land experiences increased vegetation productivity and higher nutrient levels that are good for plant growth. However, this transition has yet to happen in recent years; the rainy season is getting longer, and the dry season is shorter. This situation is explained by AHM farmers as follows:

> There have been seasonal changes that have occurred in the last two years. The change in question occurs in the rainy season. It has been two years of very few dry seasons and mostly rainy seasons. During the rainy season, strong winds can be felt, and in the dry season, the wind is not so strong (AHM farmer, 61 years).

AHM farmers have felt the change of seasons over the past two years. Strong winds accompany longer rainy periods. AMR farmers also feel these seasonal changes. The dry season is shorter, less than one month, as was explained by the AMR pack:

> The rainy season has continued for almost three years; the dry seasons were not long (less than one month) and then the rainy season started again. If normal, usually in the middle of the year, the rainy season starts, but it has been going on for three years. The rainy season occurs continuously (AMR farmer, 40 years).

The explanation of AMR farmers is the same as the explanation of the DMT farmers, who stated that:

> It has been almost three years since the weather in Kahayya Village was primarily rainy compared to the dry season; sometimes, the weather is hot but this does not last long (7 to 10 days). Usually, the rainy season in Kahayya Village occurs in the middle of the year. However, it has been different for the last three years (DMT farmer, 41 years old).

In recent years, farmers have needed help to predict seasonal shifts. Because the dominant rainy season and short drought cause coffee plants to be unproductive, the farmers never felt that the dry season had arrived in 2022. Coffee plants require hot (dry) conditions for approximately 20 to 30 days. Coffee farmers feel the impact of the uncertainty of the change between the rainy and dry seasons. This situation is expressed by ASR farmers as follows:

> The current season is difficult to predict, even though month one is usually the rainy season. Similar to the dry season, it is also difficult to predict because there has been no dry season for three years. The seasonal changes of the last two years are very pronounced; plants such as coffee and cloves need a sufficient amount of sun. Usually, coffee plants require hot conditions for 20 to 30 days (ASR farmer, 48 years).

Climate change is being felt by the Kahayya Village coffee farmers, characterized by changes in the wind patterns, wind speed, and uncertain weather. Based on research (Ebisa, 2017), the spread of rain throughout the year causes coffee to flower unexpectedly at various times, allowing farmers to harvest small amounts of coffee continuously.

5.1.2. The weather is sunny in the morning but only for a short time, then cloudy, and then rainy

Climate change is a long-term change that has an uncertain effect on weather conditions, namely sunny weather in the morning that turns cloudy and then it rains. The uncertainty of the weather has an impact on the environment and the daily lives of coffee farmers. The JMH farmers describe this phenomenon as:

> The seasonal changes that occur now are mostly in the rainy seasons; strong winds have also recently occurred, which resulted in many trees falling and flying leaves. The sky is cloudy every day, sometimes the sun is visible, but after a few hours, it will rain again (JMH farmer, 50 years).

Weather uncertainty causes the farmers to suffer losses because they cannot dry their coffee and corn crops. Insufficient sunlight can accelerate the decay of coffee and corn crops. This condition is felt by IRN farmers, who stated that:

> What can be noticed when there is a change in the weather is the sky turns cloudy if there is rain. Moreover, when it is sunny, then it will not rain. However, what often happens at this time is that in the morning, the weather is very sunny, so people who want to dry corn are happy because they think that the weather will remain sunny, but by noon, the weather turns cloudy, and soon it rains. Therefore, predictions or observations of weather change signs are rarely correct (IRN farmer, 28 years).

Uncertainty about the weather, and the losses experienced by farmers due to climate change have been occurring for three years. Usually there are sunny weather conditions in the morning, then rain in the afternoon. This usually signifies the end of the rainy season. However, this condition occurs throughout the year, as explained by RST farmers:

> For the past three years, the residents of Kahayya Village have complained about the change of seasons that continue (often raining), and there is rarely any sunshine. Sometimes the morning is sunny but then it rains again in the afternoon. Parents used to say that the morning was always sunny. It indicates that the rainy season is almost over, but what is felt is that there have been three years of bad weather (RHN farmer, 50 years).

The phenomenon of the uncertainty of the weather, with sunny weather in the morning followed by clouds and rain was also explained by RST farmers, who stated that:

> For almost three years, the weather in Kahayya Village has been erratic—continuous rain. Sometimes there is sunshine but a few days later it will rain again. Moreover, the sky always looks cloudy (RST farmer, 24 years old).

Climate change makes coffee farmers experience anxiety because their coffee plants, horticultural crops, and clove plants experience decreased productivity. In addition, they need help predicting the weather. Comparing the substance of the coffee farmers' knowledge about climate change illustrates changes in the wind's speed and pattern. In recent years, strong winds blow early, around the beginning of December. Previously, they usually came in January-March, which caused the plants' leaves to fall, the plants to fall, houses to collapse, electricity poles to tilt, and the roofs of residents' houses to fly off. In 2022, strong winds blew 3 to 10 days earlier in the 12th month. These vital wind events occur every year and usually coincide with rain.

Wind patterns and speeds affect changes in the more extended rainy and shorter dry periods. The people living in Kahayya experience rain throughout the year, and hot conditions only last for 7 to 10 days. Meanwhile, the temperature is warmer than usual. Long periods of rain, intense winds, and warmer temperatures hurt farmers, because the productivity level of coffee plants has decreased. Because coffee plants need sufficient quantities of sun, they usually need hot conditions for 20 to 40 days in a row.

Changes in the wind's speed and the seasons have implications for the farmers' livelihood systems. The recent increased and prolonged intensity of the rain has made it difficult for farmers to distinguish between the classification of the seasons, between the rainy season, the transition season, and the dry season, as it currently only feels like continuous rain. Climate change undermines the relevance of local knowledge systems and the farmers' wisdom. Farmers find it difficult to predict the right season for cultivation. In addition, climate change makes it difficult for coffee plants to bear fruit, due to different fruiting systems and irregular harvest seasons. Ultimately, it causes a decline in the farmers' incomes because the productivity of their coffee plants decreases.

Such conditions also occur in some countries; for example, in Ghana, where the hours of sunlight have been increasing and becoming more prolonged lately, making agricultural work difficult during the day and affecting crop yields and human health.

Similar findings were found in Northern Nigeria, where high solar intensity reduced the farmers' yields, as it causes damage and challenges for harvesting tubers such as yams and potatoes. These food crops quickly rot in the scorching sun and cause high post-harvest risks. This condition illustrates that climate change increases coffee farmers' vulnerability and undermines the relevance of their knowledge (Farauta et al., 2011; Scodanibbio et al., 2023).

5.2. The process of building coffee farmers' knowledge about climate change

5.2.1. The weather is sunny in the morning but only for a short time, then cloudy, and then rainy

Coffee farmers' knowledge inheritance system about climate change is a process in which knowledge, experience, and practices related to climate change are transferred from the older generation of coffee farmers to the younger generation of farmers. The inheritance process is carried out through an oral culture to transfer valuable knowledge on how to face challenges and manage the impacts of climate change in the context of coffee farming:

> The source of seasonal knowledge is obtained from the stories of parents and experiences that have been felt. This knowledge is acquired by itself, meaning that if parents tell stories, then that is where knowledge begins to be given (BHR farmer, 29 years).
>
> The source of this knowledge was obtained from parents telling stories. This knowledge is obtained by listening and following what has been taught by older people (DMT farmer, 41 years old).
>
> Knowledge related to the signs of seasonal changes such as flying ant is known from ancestral stories and personal experience. Every time we enter the rainy season, there will be larges of flying ants will gather near the lamp (ERT farmer, 36 years).
>
> This knowledge was obtained from my father (Mr. Mansur). He often shared his knowledge. Sometimes, if you are curious about something, you can ask him. He always said that the knowledge possessed is hereditary and learned since childhood. I gained this knowledge by asking him (Mr. Masur), or sometimes he related it himself to his children (HJH farmer, 24 years old).
>
> Knowledge related to weather changes is obtained through the parents' stories, and it is also obtained when still in high school, as said earlier (HKM farmer, 28 years old).
>
> This knowledge was obtained from the teachings of the ancients. They also got this knowledge from Lontara, who was descended from the son of the prophet (KMS farmer, 73 years old).
>
> Knowledge related to the seasons was obtained from those people who came before. It is still being determined who first spread the knowledge, but the knowledge is commonly known by the people of Kahayya Village. This knowledge comes from the closest people (relatives) (MHN farmer, 43 years old).
>
> This knowledge was obtained from the ancestors who first settled here. If counted, then six generations have received this knowledge, which was inherited from the

prophet's descendants. The descendants of the prophet passed on this knowledge through Lontara, which was then taught to the people (MSR farmer, 60 years).

This knowledge includes understanding weather patterns, seasonal changes, crop cycles, and relevant practices for tackling climate change. Coffee farmers who have years of experience growing coffee in their environment naturally develop a deep understanding of how climate change affects the coffee's growth, quality, and yield.

The inheritance of climate knowledge through talking or a storytelling culture is ingrained (hysteresis) in society. The learning process has become a tradition to explain climate change events, or phenomena, to form a habit (habitus) and a cognitive structure for individuals and communities to respond to changes around them.

Knowledge about climate change is also obtained from learning about the environment by looking at natural signs, as well as the life experiences of the older generations, or the farmers themselves. For example, flying ant at night indicates the change of the seasons, from the dry to the rainy season.

The inheritance process is carried out through lessons from life experiences and questions and answers between parents and children. A dialogue between parents and children can strengthen a child's understanding of the situation he or she is experiencing. The inheritance of knowledge about climate change is not only carried out in family institutions. Young people also gain knowledge about climate change through formal educational institutions.

Knowledge is also passed down through an oral culture or tradition. The ancestors of the Kahayya coffee farmers were familiar with written traditions; knowledge about climate was also obtained from palm-leaf script written by their ancestors, which became guidelines for life, and guidelines for farming, but the origin of seasonal knowledge is difficult to trace. Climate knowledge has become common sense; almost all coffee farmers understand the climate. However, knowledge passed down from generation to generation has yet to be developed, or will not be developed by the next generation. Farmers rely more on intuition to explain things to the next generation.

To understand the climate or the weather, coffee farmers believe that such knowledge came from the first people living in Kahayya Village, whose source of knowledge was derived from the prophet's descendants. The knowledge of the descendants of the prophet was inherited through palm-leaf script. Local knowledge plays a vital role in the management and development of gardens (Isaac et al., 2009). Apart from the inheritance system through their oral culture, farmers also learn through life experience or learning from nature. The learning process shapes their knowledge and cognition as they respond to climate change. The inheritance of knowledge can be achieved through direct involvement with what will be known (Hematang and Pamuttu, 2021).

5.2.2. Formation of cognition

The formation of cognition refers to developing an individual's consciousness, knowledge, understanding, perception, and ability to perceive the surrounding world. The development process involves interaction and learning about the environment and social life. The cognitive formation of coffee farmers is studied in light of environmental changes. ASR coffee farmers put forward this explanation:

> Farmers learn to read the seasons and weather from year to year to get good agricultural results. In this learning process, farmers can recognize the characteristics of fruit that is ripe for harvest and when it is appropriate to start a plantation. Seasons are also studied to increase the yield. In the past, achieving good harvest results did not require the use of fertilizers and pesticide, but now you have to use fertilizers and pesticides to get good harvest results (ASR farmer, 40 years old).

The cognitive knowledge of farmers is generally formed by two things, namely, the process of direct observation of the environment and the learning process from their parents. The experience and learning from the environment are confirmed by the village elders (community leaders). The community considers the village elders to have the authority to interpret the climate because they have greater experience and more extensive knowledge, compared to the younger generation. This explanation was conveyed by ILM farmers, who said that:

> The possessed knowledge relates to climate change, and is only obtained from personal observations and our parents' stories. This knowledge is gained by observing things directly, and sometimes asking our parents. The development of knowledge about the season is carried out by simply digging for more information from our parents, because we think they have more experience, so the knowledge they have that is related to it must also be better known (ILM farmer, 26 years).

Knowledge about climate change is gained through discussions and stories among farmers. The results of the discussion are based on the experience of reading star signs. The villagers deeply understand the constellations and the changes in the seasons. This explanation was put forward by MSR farmers, who stated that:

> This knowledge is obtained by discussing or telling stories. This knowledge can also be obtained from people with experience of observing star signs. In this village, the person who has more profound knowledge related to the signs of seasonal changes is Puang Tanni (MSR farmer, 60 years old).

Knowledge about climate change is gained by studying plant behavior. Farmers observe the flowering period of certain plants, which indicates the arrival of the rainy season. NDA farmers said:

> In addition, this knowledge is also sometimes known by itself; for example, some flowers bloom in the late rainy season, then this will later be used as a comparison with the coming year to determine whether every year it will be like that again (NDA farmer, 39 years).

Observations of plant behavior are matched with constellation readings that were already known to the village elders. The understanding of the constellation was obtained from a village elder named Deng Tanni, who often shared his knowledge with the younger generation. This opinion is expressed by the constitutional farmers, who said that.

> The signs of star calculation were learned from Deng Tanni, who was one of the community leaders who was quite aware of the signs of seasonal changes (UDD farmer, 50 years).

This explanation was later confirmed by Mr. KMS, who stated:

> This knowledge was obtained from previous generations, but the one who understands this knowledge better is Mr. Tanni. He is the one who best understands this kind of knowledge. We also often ask him about how the season is progressing. Many understand this understanding. At this age, many have forgotten (KMS farmer, 73 years old).

The results of the analysis of the interviews found that the farmers' cognitive abilities were formed through two processes: learning from the environment by studying star movements along with plant behavior, and discussing with fellow farmers using the oral cultural tradition. The local knowledge that is shared is unique and contradictory, so it must be validated (Cerdán et al., 2012). This understanding of change has been ingrained for a long time in coffee-growing communities. Embedded knowledge about climate is used as a basis or guideline in farming. Coffee crop management is primarily influenced by external sources (an a priori form of knowledge), whereas tree-specific knowledge (coffee) is primarily generated by personal experience (empirical knowledge) (Valencia et al., 2015).

5.2.3. Discussion among farmers

The discussions by fellow farmers on climate change are an interactive forum that aims to provide a space for farmers to share their knowledge, experience, and thoughts on the impact of climate change on the agricultural sector. These discussions are held to increase the understanding of climate change among farmers, and encourage collaboration and innovation in facing the challenges posed by climate change.

In these discussions, farmers can exchange information about the weather changes they are experiencing, such as unpredictable rain patterns, fewer dry periods, more intense pest infestations, and longer growing seasons. They can also share adaptation and mitigation strategies they have tried, or new ideas to meet these challenges. Discussions among farmers became a medium for them to exchange ideas. Farmers can gain a new understanding of climate change and the commodities to be planted through this medium. This explanation was obtained from AHM farmers, who said that:

> The media used is discussion or storytelling (AHM farmer, 61 years old).

In the discussion forum, farmers confirmed that the understanding they gained came from the learning process about the environment; this explanation was obtained from ASR, who argued that:

> I learned about the season from experience. Experience was gained through discussions with my parents; it has been like that. Usually, 2 to 3 farmers tell each other stories (ASR farmer, 48 years old).

The discussion forum for farmers is a place to shape people's cognition; knowledge about climate is often used as a topic of discussion to exchange ideas. This forum is a place to disseminate climate information about agriculture. This statement was put forward by FRN farmers, who stated that:

> This knowledge (climate change) is not disseminated because it is common knowledge, so many other people know about this kind of science… This knowledge is spread if you are gathering with family and again discussing something like that, then this knowledge will spread by itself. Discussions or

> telling stories (are usually) when gathering with family (FRN farmer, 28 years old).

An understanding of climate change is obtained through discussions among farmers; discussion rooms become places for the exchange and dissemination of information. These discussions are used as a medium for forming public opinion to bring together all the farmers' interests and compile a better understanding among the farmers. However, the construction of knowledge about climate change is strongly influenced by the elders of the coffee farmers. Continuous interactions carried out by farmers can provide space for innovation to emerge (Hermans et al., 2023).

5.2.4. Learning from village elders

Learning from village elders about climate change is a concept that recognizes the valuable knowledge and experience that the village elders or traditional figures have in dealing with climate change. They often have a deep understanding of the local environment, natural cycles, and climate change that has occurred over time. The process of learning from village elders includes listening to their stories and experiences, and learning about their traditional practices and knowledge in dealing with climate change. This can include knowledge of the plants and animals that are resistant to changing climates, sustainable farming techniques, or weather forecasting methods. This acts as a mitigation measure to reduce or handle risks that will occur (Astaman et al., 2023). This view was expressed by YSF, who said that:

> This knowledge is usually obtained from the stories of our ancestors and then used by the people around today. In this village, the one who is famous for knowing this knowledge is Puang Tanni. He was the only person who knew enough to predict the weather. Many insights are obtained from the stories of the ancients. I also sometimes go to Puang Tanni's house to ask about the weather changes he sees or notices (YSF farmer, 75 years old).

Village elders have often observed climate change firsthand and faced the challenges associated with such changes. They can understand weather patterns, growing seasons, and the changes in biodiversity that are happening around them. This knowledge is often passed down from generation to generation and becomes part of the local wisdom. This explanation was conveyed by Mr. JFR, who said that:

> The knowledge of reading seasons was passed from generation to generation by Mr. Jufri's family. When he was a teenager, Pak Jufri learned how to read the seasons from his cousin, Pak Doleng. Pak Jufri later wanted to know how to find the weather forecast, but Pak Doleng had died.
>
> Jufri also got this weather forecasting knowledge from Pung Tanni. Pung's farm is adjacent to Pak Jufri's. Usually, at nightfall, Pak Jufri visits Pung Tanni's Garden house to learn to read the weather forecast. According to Pak Jufri, Pung Tanni is the only elder in Kahayya Village who is an expert at reading weather forecasts. Pak Jufri said the science of reading the season is the inheritance of the guardian that God gave to be used by farmers, who have believed in it for generations. Another source for reading seasonal knowledge is from Mr. Pak Jufri. He is named Pak Tingko (JFR farmer, 55 years old).

This view is reaffirmed by one HR farmer, who stated that:

> This knowledge of climate is obtained from generation to generation. However, if you want to know who the person is who understands the knowledge of estimating the season, then people around will certainly always say it is Puang Tanni. Until now, only he understands this so well (HR farmer, 45 years old).

Involving village elders in efforts to tackle climate change can provide valuable insights for the younger generation, and the general public. They can share local knowledge on how to adapt to climate change, methods of forecasting the weather, and maintaining an environmental balance. These methods are illustrations of the relationship between indigenous peoples and nature, as well as knowledge of the coffee ecosystem that has been passed down from generation to generation (Torres Castillo et al., 2020). Arifah et al. (2023) added that the essential players who were engaged in spreading information regarding climate change adaptation also had crucial roles in the knowledge transfer process.

5.3. Social network for coffee farmers' knowledge construction

Figure 3 shows that there are two groups for climate knowledge's construction formation, the Puang Tanni group and the Puang Lappe group, which is not related to the Tanni group's social network. However, the central actor in the formation of climate knowledge construction is Puang Tanni. However, Puang Tanni was influenced by Puang Aco and Puang Baco Palu. The formation of social networks, in the construction of knowledge in the Puang Lappe group, is explained by AHM farmers, who say that:

> Knowledge about climate change was obtained from my father-in-law (Puang Lappe) (AHM farmer, 61 years).

The community leader who became the central figure in the construction of knowledge about climate was Pak Jufri, who was supervised by his relatives. This explanation was expressed by JFR farmers, who said that:

> The knowledge of reading the seasons was passed from generation to generation by Mr. Jufri's family. Pak Jufri got his knowledge of reading the seasons when he was a teenager from his cousin, who was called Pak Doleng. Pak Jufri also got this weather forecasting knowledge from Pung Tanni. Puang's farm is adjacent to Pak Jufri's. Usually, at nightfall, Pak Jufri would visit Puang Tanni's garden house to learn to read the weather forecast. Another source for obtaining knowledge about reading the seasons is Pak Jufri, who is also called Pak Tingko (JFR farmer, 55 years old).

The affirmation of Puang Tanni as a central figure in the formation of this knowledge construction was also explained by KMS farmers, who said that:

> This knowledge was obtained from previous generations, but the one who understands this kind of knowledge best is Mr. Tanni (KMS farmer, 73 years old).

The same explanation is expressed by MSR farmers, who said that:

> In this village, the one who has more profound knowledge related to the signs of seasonal changes is Puang Tanni. People who are curious about this knowledge will usually ask him (MSR farmer, 60 years old).

Puang Tanni's role in the formation of social networks for the process of knowledge construction about climate was reaffirmed by HR:

> This knowledge about the climate is passed from generation to generation. However, if you want to know who is the person who best understands the knowledge for estimating the season, then people around will certainly always say it is Puang Tanni. Until now, only he understands all this so well (HR farmer, 45 years old).

Puang Tanni, as a central figure in the formation of knowledge construction about climate, was also mentioned by SLE, who stated that:

> This knowledge is obtained from our parents' teachings and asking people who are more familiar with this kind of knowledge (Deng Tanni) (SLE farmer, 60 years old).

The interaction and social networks of farmers play an essential role in their decisions about what actions to take, both for the mitigation of, and adaptation to, climate change (Tan et al., 2023).

5.4. Action consequences of constructed knowledge about climate change

5.4.1. Waiting for the climate to improve

Waiting for the climate to improve refers to people's attitudes to taking concrete action to adapt to climate change. Farmers hope the climate will "improve" in the coming year. This expectation encourages farmers to choose to look for other jobs outside the village while waiting for climate improvement, as explained by RSM farmers who said that:

> There is no action because coffee plants need a relatively long dry season to produce plentiful beans. After all, if there is a long rainy period, you only get a lot of leaves (RSM farmer, 24 years).

The attitude of these farmers shows that they are very skeptical about facing climate change by not taking any action on their coffee farms so that the coffee trees can bear fruit well. They prefer to wait for the season to improve while looking for other work. This skepticism was demonstrated by SR farmers who say:

> The rainy period is longer in Kahayya, with 1 to 2 weeks of rain, and the dry season is only three days. There is no time to look for a side job outside. If I do not take any action, I must wait for the production to improve because this has been happening for three years (Sri farmer, 38 years old).

ANS farmers also conveyed the skepticism of coffee farmers and actions affecting their crops:

> Because of this change to a more extensive rainy period, the actions of farmers here to take care of their crops are still as usual. However, many people have left the village to find side jobs, such as cutting rice in Bulukumba, because they expect coffee and clove yields to significantly decrease (ANS farmer, 48 years old).

Farmers also carry out minimal maintenance activities during uncertain climatic conditions and hope that the weather becomes more stable. Farmers continue to fertilize, clean weeds, and prune, as explained by TNN farmers, who said that:

> The action, yes, staying in the garden to do the maintenance is all I can do, and I hope the weather will be good again. Still, work as usual, fertilize, prune, clean weeds, and hope the weather will improve again (TNN farmer, 67 years old).

Coffee farmers also need clarification about the uncertainty of the weather. Farmers can only wait for the climate to improve while caring for their plants, because coffee plants require a long hot climate. This statement was conveyed by MSR farmers, who said that:

> Suppose I am more routine in caring for my plants. For coffee itself, it does need a drought to make the yield good again, because this rain makes the coffee flowers fall; only the leaves get denser. So, if I take no action as usual, the treatment is because I am confused about what happens if the drought is shorter (MSR farmer, 60 years).

Some farmers are skeptical about waiting for the climate to improve and normalize as in previous years. Farmers waiting for their average climate do nothing but take care of their coffee plants and find other sources of livelihood. The results of a study by Tan et al. (2023) found that farmers in Italy carry out crop rotation methods, adapting to climate change by delaying rice planting in winter and spring, and, based on local knowledge and experience, they predict weather patterns by planting corn earlier than usual, to avoid droughts and floods.

5.4.2. Coffee treatment gets more intensive

Weather changes have a strong relationship with the intensification of coffee treatments. Coffee plants are susceptible to disruption and the risk of failing to bear fruit and provide a harvest when climate change occurs, such as unpredictable rainfall or unstable seasonal patterns. In the face of these challenges, coffee farmers are likely to increase the intensity of their care they give to their crop. Also, they devote more time because they have to harvest many times and more irregularly. HKM farmers conveyed this concern:

> Currently, coffee farming activities are irregular; farmers have to spend a lot of time harvesting. Coffee cherries cannot be harvested simultaneously because coffee beans mature gradually (HKM farmer, 28 years).

This view is confirmed by ILM farmers, who state that:

> The erratic rainy season results in coffee harvesting activities that are carried out gradually, or every month, because coffee beans that are unevenly ripened or flowered do not simultaneously appear. Although it is done monthly, the results are minimal (ILM farmer, 26 years old).

With more prolonged and more intensive rainfall, farmers must prune any protective plants more intensively to provide light to their coffee plants so they can bear fruit well. This complaint was submitted by JFR farmers, who said that:

> Protective trees are pruned if the rainy season is continuous, because very little sunlight shines on coffee plantations (JFR farmer 55 years).

Prolonged rains require intensive care, as expressed by NRD farmers, who state that:

> Care such as pruning used to be expected if you wanted a harvest, but for now, pruning activities are erratic (NRD farmer, 38 years old).

During the intensive rains in Kahayya Village, farmers devote more time to caring for their coffee plants, especially at harvest time, pruning the protective plants, and the coffee plants themselves. This action is explained by an AHM farmer, who stated that:

> Suppose the actions toward the plants involve more frequent pruning, fertilizing, and clearing the land, which is all we can do. In that case, it has little effect and is different from doing maintenance and not doing maintenance at all during the more extended rainy periods, and looking after the plants by pruning and fertilizing as usual (AHM farmer, 61 years).

Climate change can be anticipated by carrying out intensive encouragement treatment measures in the mornings. This action is to provide sufficient sunlight for the plants. This action is explained by UDN farmers, who say that:

> For coffee, according to my grandfather, it makes sense to prune plants in the morning so that the sunlight can reach the trunk of the coffee tree and enter it before the rain comes later in the day (UDN farmer, 50 years old).

The most effective action in the rainy season is pruning the coffee plants by clearing the young shoots. This pruning is beneficial for increasing coffee plant yields. This explanation was expressed by ILM farmers, who claim that:

> Yes, it rains more often…the action I take, especially as a coffee farmer, is pruning, namely reducing the stalks of young shoots or new shoots and clearing the weeds from under the coffee trees. But, the most effective action is when there is often a rainy season, because, little by little, it affects coffee production, so I consider this important to do now (ILM farmer, 24 years).

However, the study's results, put forward by Nadaleti et al. (2018), show that pruning does not increase plant productivity. Another action farmers take in the face of climate change is commodity diversification, by planting corn and vegetables. These horticultural crop commodities are the economic support of coffee farmers. This explanation was conveyed by MRN, who said that:

> This has happened for the last three years because there are also many crops whose yields are still good, such as corn, which is essential to be cared for. It is like cloves and coffee, whose production has significantly decreased, so yes, I then thought I could not just focus on those two things, so I tried to grow vegetables to provide a side income (MRN farmer, 30 years).

Facing more extended rainfall, coffee farmers try to adapt to their situation. One strategy carried out by the coffee farmers is to sell their coffee fruits directly to traders. HJH explains that:

> My actions for the last three years with such conditions (the rainy period getting longer) specifically for coffee, the action is still as usual; caring for the plants (pruning and weed cleaning) but more often pruning new shoots. In the past, I usually processed coffee from cherries to green beans after harvesting them, but now, because the rainy period is getting longer, it is not easy to dry, and the yield is getting less, so I do not process coffee anymore. I sell the cherries because the price has increased two times (HJH farmer, 24 years).

Sheltered coffee systems are an effective strategy to increase the resilience of coffee plants to extreme climate change. Shading systems can protect coffee plants from high solar radiation, heavy rain, and pest attacks (Chain-Guadarrama et al., 2019; Fain et al., 2018; Harvey et al., 2017). In addition, pruning also reduces the amount of inoculum contained in the soil, which increases the risk of infection in the coffee plants (Gonzales et al., 2023). Pruning activities to remove shoots or side stems are carried out selectively, in order to minimize the growth of other plants, the risk of plant

diseases, and the efficiency of photosynthesis, as well as creating organic matter and carbon binders for the soil (de Sosa et al., 2023; Gokavi et al., 2021). Pruning is also used to reduce plant maintenance costs and, at the same time, it becomes a semi-mechanical harvesting technique (Jose et al., 2017).

5.4.3. Harvesting is carried out gradually according to the ripeness of the coffee

In unstable weather conditions, coffee berries do not ripen uniformly on the tree. Some fruits can reach optimal maturity, while others still need to fully ripen. If farmers choose to harvest all the coffee fruits simultaneously, they will reduce the optimal yields and the quality. In dealing with this situation, farmers tend to harvest gradually, which means harvesting coffee fruits sustainably according to the desired level of maturity. This view is conveyed by AHM farmers, who say that:

> Coffee beans also bear fruit unevenly, so coffee farmers often check coffee beans to see if they have changed color and are ready to be harvested (AHM farmer, 61 years).

Irregular rain patterns make harvesting activities more routine than in previous years. This explanation was conveyed by ASR farmers, who stated that:

> Sometimes it rains, sometimes it is dry, coffee plants usually bear fruit continuously, which is good. However, the number of the fruits is decrease. Coffee plants can bear fruit three times a year, now usually only twice a year but the fruit does not ripen at the same time. Sometimes some are already flowering, some are almost old, and some are still small (ASR farmer, 48 years).

Intensive rains also cause a slowdown in coffee growth. This problem was conveyed by ERT farmers, who claim that:

> Coffee growth is also hampered due to weather changes. As a result, coffee does not ripen evenly, which results in us harvesting many times (ERT farmer, 36 years).

Uneven coffee fruits are the cause of routine harvesting activities; IBR farmers gave this explanation:

> Coffee harvesting activities are generally carried out once a year, but now coffee harvesting activities are carried out gradually because the coffee beans do not ripen evenly (IBR farmer, 40 years).

The same explanation was also expressed by IRN farmers, who stated that:

> Usually, coffee harvesting activities are carried out once a year. However, with the current conditions, coffee yields do not ripen evenly, so farmers routinely check if there is coffee that is ready to be harvested (IRN farmer, 28 years).

The same thing was also conveyed by MHN farmers, who said that:

> In addition, harvesting activities are normally carried out once a year, but currently, harvesting activities are carried out every month because coffee beans ripen unevenly. Although harvesting activities are carried out every month, the yields are much less when compared to a harvest carried out once a year (MHN farmer, 43 years).

Regular harvesting due to seasonal changes is reaffirmed by SDM farmers, who said that:

> Coffee farming activities certainly change due to seasonal changes that occur. Usually, coffee is harvested once a year, but now, coffee is harvested almost daily.

> Although coffee used to be harvested only once a year, the results obtained were much better compared to now. Every month, coffee is harvested, but the yield has decreased dramatically (HR farmer, 45 years).

Gradual harvest adjustments, according to the coffee's maturity, is a strategy the farmers use to adapt to changes in the weather and the climate. In addition, terracing is one of the adaptive strategies for facilitating the harvesting and maintenance of coffee plants (Fain et al., 2018). By considering the weather's variability and the ripeness patterns of coffee fruits, farmers can optimize the yields and ensure a better quality. It can also help them deal with challenges that may be associated with climate change in the long run.

5.4.4. Finding alternate methods to dry coffee

There are consequences resulting from the actions that farmers must take when adapting to the situation they face. The impact is most pronounced during climate change; coffee plants require intensive care and post-harvest processing. This explanation was revealed by HJH farmers, who noted that:

> I went to the garden earlier, and the care for the plants became more intensive. For drying the crops, I usually dry them in the attic of the house, or I make a drying place under the house, even though sometimes the results are not very good (HJH farmer, 24 years old).

Little sunlight and extended rainfall forced them to make greenhouses to improve their coffee's quality and selling price. Greenhouses can help coffee farmers dry out green beans (coffee beans) after harvesting. This action is explained by AHM farmers, who say that:

> Suppose the action itself is to make a greenhouse for drying so that crops can be good without having to have direct sun in our garden. In that case, we go to the garden early to take care of the plants; for example, we fertilize them even earlier (AHM farmer, 61 years).

To get around climate change, in addition to making greenhouses, coffee farmers use the attics in their homes to dry the beans because the temperature is hot and this dries the coffee quickly. This explanation was conveyed by ILM farmers, who say that:

> This usually affects post-harvested coffee and cloves. But especially for drying coffee, I already have a greenhouse for drying coffee, and other alternatives, because we have an attic where the temperature is hot because of the distance from the roof, so we use it for drying cloves and coffee (ILM farmer, 24 years).

RST farmers do the same by utilizing the attics in their homes for drying coffee and clove plants. They explain that:

> If our action is, for example, to dry the coffee, then I use the house's attic for drying the coffee and cloves. Facing weather that is not conducive to drying coffee, then I use the house's attic for drying coffee and cloves. I did not provide any treatment while drying was taking place on the house's attic. I'm just waiting for the coffee beans and cloves to dry. Drying on house's attic can help speed up the drying of coffee (RST farmer, 24 years old).

The adaptation process is carried out by farmers in various ways, including utilizing the morning sun. They dry their coffee in the morning, and after the weather

becomes cloudy, they put it back in the house. This explanation was conveyed by SRI farmers, who said that:

> Usually, coffee harvesting activities are carried out once a year. However, with the current conditions, coffee yields do not ripen evenly, so farmers routinely check if there is coffee that is ready to be harvested (IRN farmer, 28 years).

The same thing was also conveyed by MHN farmers, who said that:

> Yes, sometimes we expected it to be sunny until the afternoon, but it turns out that at 11am it gets cloudy again. Yes, the action is that if I dry my agricultural products, I dry them early, so when it is cloudy in the afternoon, I save them again and dry them the next day (SRI farmer, 38 years old).

During the three years of climate change, the coffee farmers started to work early. They had to adjust to the weather conditions. The pruning process was carried out early and post-harvest activities for drying the coffee beans were carried out in a greenhouse. This action is disclosed by ASR, who stated that:

> I usually start work in the garden early, so that when it gets cloudy, the work in the garden finishes. However, such weather affects crop production and has an impact on the post-harvest coffee, cloves, and tobacco, because drying them requires sunshine. Because of the weather, we in Kahayya use greenhouses to dry the coffee and cloves. For tobacco, it is very troublesome (ASR farmer, 48 years old).

The advantage of starting early is that work such as pruning and harvesting is completed when the clouds arrive. This explanation was conveyed by TN farmers, who said that:

> Go to the garden earlier, so that when it is cloudy, the work in the garden has been completed (TN farmer, 61 years old).

MRY farmers also carried out the same activity, and coffee farmers arrived at their plantations at 06.00 (central Indonesian time) in the morning. They carried out the process of weeding, cleaning and fertilizing. This activity was conveyed by MRY farmers, who said that:

> I go to the garden early, sometimes at 6 o'clock. I clear the weeds around the beans and fertilize them in the morning so that the fertilizer will soak in well when it rains during the day. If it is coffee, because now the yield is small, I have a greenhouse for drying, so even if it rains, my coffee is still safe (MRY farmer, 30 years old).

The same action was also taken by MSR farmers, who reported that:

> Usually, after morning prayers, I am already in the garden close to my home to clean up the weeds around my plants, so by noon, when it is cloudy, the work in the garden is finished. To dry the coffee, I dry it in the attic of my house, along with cloves and corn (MSR farmer, 60 years).

The most difficult challenge faced by coffee farmers over the past three years has been post-harvest processing. Farmers are constrained in the drying process due to a lack of sunlight. This obstacle was conveyed by UDD farmers, who said that:

> When drying coffee...the most challenging thing is that the drying does have to be in direct sunlight, so I usually wait in this drying place. When it gets cloudy, I put it back under the house. For coffee, according to my grandfather, it is still

> wise to prune the plants in the morning so that the sunlight can enter the trunk of the coffee tree before the rain comes during the day (UDD farmer, 50 years).

The adaptation strategy carried out by coffee farmers to face climate change is to start work early in their gardens, to clear the weeds, prune the coffee plants, and fertilize them. In addition, the strategy of post-harvest farmers is to make greenhouses for drying. Solar dryers work on the same principle as greenhouses: Solar energy is captured by manifolds, which increase the air temperature (Tan et al., 2023). Drying in a greenhouse usually takes three days to reach a moisture content of about 12% (Siagian et al., 2017), and the time efficiency is about 50% compared with traditional or direct solar methods (Amiruddin et al., 2022). This strategy dramatically helps farmers increase their coffee yields, while maintaining the quality of their coffee beans, and reducing microorganism contamination.

5.4.5. Looking for alternative sources of livelihood

Finding alternative sources of livelihood can be an adaptation response to climate change that cannot be addressed directly in the context of agriculture. By seeking more diverse sources of livelihood, coffee farmers can reduce the economic risks and vulnerabilities caused by climate change. It can also provide them with additional sources of income and diversify their family's economic resources. NRD farmers conveyed this concern:

> This knowledge is undoubtedly applied; for example, coffee yields decrease during a prolonged rainy season like this, so try to maximize other work. The current season is already difficult to predict, so if you continue to wait for bad weather, it is better to find another job (NRD farmer, 38 years old).

The decline in coffee farmers' incomes encourages them to look for alternative sources of livelihood. They chose to leave their villages and migrate to various regions of Indonesia. This step was taken to survive and meet the needs of coffee farmers' households. ASR farmers conveyed this explanation:

> If the dry season is short, fruit and agricultural products become scarce. Many people go out of the village. Some went to Bulukumba District, many to Kalimantan, and to Malaysia, to work in oil palm plantations (ASR farmer, 48 years old).

The time when the farmers migrate depends very much on the weather conditions they face. They will migrate during a more extensive rainy season. However, there are some farmers who choose to stay in their village, to keep caring for their coffee plants. JFR farmers conveyed this explanation:

> Usually, weather forecasts affect people's decisions to travel. If there is a change in the weather like this, people choose to go abroad or build a dwelling in the city because there are no results that can be obtained by us coffee farmers planting other crops (JFR farmer, 55 years).

The changing weather conditions faced by farmers have dealt a heavy blow to farmers. Coffee farmers are only given two choices: to migrate or survive in inadequate economic conditions that cannot meet their needs. This view is expressed by NRD farmers, who said that:

> Coffee yields decrease; therefore, we try to maximize other work. The current season is difficult to predict, so if you continue to try to survive by waiting for bad weather, it is better to find another job (NRD farmer, 38 years old).

This problematic situation was also conveyed by RSN farmers, who stated:

> Yields drop dramatically, then the income they generate also falls; to get additional income, people will usually leave the village to harvest rice in neighboring villages (RSN farmer, 31 years).

Climate change may push coffee farmers to look for alternative sources of livelihood outside of farming. This concern was conveyed by UDD farmers, who said that:

> This has been happening for three years, but I have taken care as usual. However, this plantation is not good if there is no solar heat. So, I found a side income by leaving the village and looking for work. With coffee, there is no action; I am still doing maintenance as usual, because I do not know how else to make the yield increase (UDD farmer, 50 years old).

Alternative sources of livelihood for coffee farmers are adaptation efforts to reduce economic risks and vulnerabilities caused by climate change. This aligns with research by Torres Castillo et al. (2020), which shows that most coffee farmers undertake other economic activities, including migration, when coffee production declines due to climate variability.

5.4.6. Reducing the fertilizer used for coffee plants

Climate change is closely related to the farmers' decisions to reduce or not fertilize coffee plants. Extreme temperature fluctuations, irregular rainfall patterns, or seasonal changes can affect their fertilization activities. With dry weather, fertilizer cannot function as optimally as it does in the continuous rainy season. This view is expressed by AMR farmers, who said that:

> The fertilization process should be done when the intensity of the rain is low. If fertilizing is carried out during the dry season, it will be difficult for it to penetrate the roots of the plants. However, the prolonged rainy season is also not suitable if fertilization occurs (AMR farmer, 40 years).

Fertilization activities are not carried out for coffee plants because they do not improve the quality of the coffee beans. This statement was conveyed by HKM, who said that:

> Fertilization activities are also not carried out routinely because the fertilizer used only affects the trees' growth, not the yield of the coffee beans (HKM farmer, 28 years).

To reduce losses of coffee farmers, they must rely on the assistance of fertilizers provided by the government. This assistance is free assistance without being charged by the government. Farmers only use fertilizer if there is free fertilizer assistance from the government. This explanation was conveyed by Mr. KMS, who said that:

> Fertilization is carried out if there is fertilizer provided by the government (KMS, 73 years).

This view is in line with YSF farmers who state that:

> Fertilization is only carried out when there is a distribution of fertilizer from the village head (YSF farmer, 75 years old).

The reduction in the intensity of fertilizing coffee plants is influenced by a decrease in the productivity of coffee farmers, which is not comparable to the costs incurred by coffee farmers. Intensively fertilized coffee crops are not able to return the capital spent by the coffee farmers. This concern was conveyed by SRI farmers, who stated that:

> Fertilization activities have rarely been carried out because of insufficient yields during the rainy season. These yields continue to fall. Income from selling coffee beans cannot cover the costs of procuring fertilizer if the fertilizer is not free fertilizer from the government (SRI farmer, 38 years).

Reducing the fertilizer used on coffee plants, in response to climate change, is a strategic adaptation step in maintaining the sustainability of the farmers' incomes. Because, in recent years, they have experienced a decline in their income. The results of research by Harvey et al. (2017) suggest that farmers can protect their coffee plantations from climate variability by using shade to reduce inputs (fertilizers and herbicides). Another strategic step in dealing with climate change is to find other sources of livelihood.

5.4.7. Adapting old knowledge to the latest experiences

Adapting old knowledge to the latest experience of climate change is essential for coffee farmers when facing the challenges of climate uncertainty. Old knowledge gained from the experiences of previous generations has become the basis of the agricultural practices passed down in peasant culture. Coffee farmers can combine traditional knowledge with more relevant weather information and forecasts to make better decisions about their farming practices. This view is expressed by IBR farmers, who say that:

> This knowledge is obtained from our parents' teachings; they always observed natural events and then compared them with previous events (IBR farmer, 40 years).

Combining old knowledge with the latest experience, coffee farmers can identify new patterns, trends, and challenges due to climate change. They can update their knowledge of agricultural practices, so that they align with the current conditions, such as timing when they plant, the use of fertilizer, pest control, and irrigation. According to Chain-Guadarrama et al. (2019) and Verburg et al. (2019), strategies that can be applied to increase the resilience of coffee systems to climate change include managing shade to reduce temperature stress, improving irrigation systems, using coffee varieties that are tolerant of temperature and drought stresses, and implementing soil conservation practices to increase the moisture content.

> What can be observed when there is a change in the season is the time or length of the season. Then, it will be compared with the previous year and the current year. However, with the seasonal uncertainty, it is already challenging to observe the signs (NRD farmer, 38 years old).

Adapting old knowledge to recent experiences should involve interaction and information sharing between coffee farmers. By communicating and collaborating with other farmers at the local and cross-regional levels, they can gain new insights, adaptation strategies, and innovative solutions to climate change.

In the face of rapid climate change, the coffee farmers' ability to continuously learn, adapt, and update their knowledge is critical to their success. Adapting old knowledge to the latest experience enables coffee farmers to face complex challenges and increase the resilience of their farms to inevitable climate change. The construction of knowledge about agriculture is dynamic and will change occasionally (Hermans et al., 2023).

6. Conclusion

In this article, we have discussed the coffee farmers' knowledge of climate change. Coffee farmers are looking for new ways to respond to and adapt to climate change. Village elders, personal experience, and collective experience influence the construction of the coffee farmers' knowledge about climate change. The construction of the coffee farmers' knowledge about climate change guides us to understand the complex situation facing coffee farmers. The construction of the farmers' knowledge of values, norms, and culture can help stakeholders and scientists determine priority policies and strategies for mitigating and adapting to climate change.

Coffee farmers understand climate change's impact on various aspects of their lives, such as crop yields, the coffee beans' quality, diseases and pests, and access to resources. The study looks at changes in rainfall patterns, humidity, and changes in weather extremes such as rainfall, drought, and hot weather that can affect coffee yields. The construction of the coffee farmers' knowledge about climate change is critical to understanding how coffee farmers respond to it, and how they can adapt to it.

The result of the construction of the coffee farmers' knowledge about climate change is the result of learning from the village elders. They acknowledge the valuable knowledge and experience of the village elders, or traditional figures, in dealing with climate change. These actions and attitudes are critical to understanding how coffee farmers build their adaptation strategies to climate change. Coffee farmers gain knowledge about climate change from their personal experiences and the collective experience gained from the village elders. They used this knowledge to develop adaptation strategies appropriate to the local conditions and their needs. Coffee farmers use a variety of adaptation strategies to deal with climate change. These include regular pruning of protective crops, diversification of the farmers' work, gradual harvesting, and the reduced use of fertilizers. In addition, coffee farmers also use non-agricultural adaptation strategies such as tourism business developments and handicraft business developments.

It is essential to acknowledge and appreciate the knowledge of coffee farmers in formulating adaptation policies and strategies for climate change. Collaboration between the coffee farmers, governments, and other stakeholders is essential for confronting climate change. Thus, this study provides valuable insights into understanding the coffee farmers' knowledge construction about climate change and the importance of integrating local knowledge into adaptation efforts to negate the effects of climate change.

The limitation of this study is that it only examined village-level coffee farmers. Coffee farming at the regional level also needs to be researched. Further research

suggests quantitative research be used to measure the intensity of using traditional knowledge in dealing with climate change

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