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Enhancing government communication for climate change adaptation: a case study of agricultural policies and practices

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Abstract

Climate change presents serious threats to highland agricultural areas such as Dieng (Central Java) and Karo (North Sumatra), where farmers increasingly experience irregular weather patterns, prolonged droughts, and frost events (bun upas). This study examines how the government communicates climate adaptation innovations—particularly through the Farmer Field School (Sekolah Lapang, SL) program and the work of agricultural extension officers (Penyuluh Pertanian Lapangan, PPL)—to support farmers in these vulnerable regions. Innovations such as the application of Lactic Acid Bacteria (LAB), Plant Growth-Promoting Rhizobacteria (PGPR), and basic frost prevention strategies have been introduced since 2022 through Farmer Field School (SL) initiatives led by local agricultural departments. Guided by Rogers' Diffusion of Innovation Theory, this qualitative research involved semi-structured interviews with six farmers and two Agricultural Extension Officers. The analysis focuses on five diffusion stages: knowledge, persuasion, decision, implementation, and confirmation. The findings show that while farmers in both regions are increasingly aware of climate change (knowledge stage), many receive information from peers or media rather than official channels. In Dieng, adoption is constrained by resource competition with tourism and limited frost response strategies. In Karo, although media use is higher, government messaging still lacks practical, region-specific guidance. The study reveals key gaps in the persuasion and implementation phases, suggesting that existing communication efforts remain too generic and insufficiently persuasive. It recommends more localized, trust-based, and multi-channel communication strategies tailored to the unique environmental conditions of each region. The research contributes to the understanding of how institutional communication can better support innovation adoption in climate-vulnerable farming communities.

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INTRODUCTION

Climate change presents one of the greatest global challenges of the 21st century, significantly impacting agricultural productivity and food security. Agricultural sectors, particularly in countries like Indonesia, which rely heavily on this industry, are highly susceptible to climate variability. Indonesia, as an agrarian nation, faces a range of climate-related risks, such as erratic rainfall patterns, prolonged dry spells, rising temperatures, and increased frequency of extreme weather events, all of which have detrimental effects on crop yields, livelihoods, and agricultural sustainability (Manurung, 2024). These changes disproportionately affect highland regions, such as Dieng in Central Java and Karo in North Sumatra, which are key potato-producing areas. In these regions, farmers grapple with heightened climate risks, including frosts, droughts, and changing weather patterns (Dewi et al., 2016).

The agricultural sector in highland regions like Dieng and Karo is particularly vulnerable due to the dependence on stable climatic conditions. Traditionally, these areas have benefited from cool temperatures that favor potato and vegetable cultivation. However, climate change has disrupted this balance, making the farming environment more uncertain and challenging. For example, frost (*bun upas*) is a recurring phenomenon in Dieng during the dry season, causing significant damage to potato crops that have yet to mature (Darmawan, 2018). In Karo, farmers face similar challenges with unpredictable rainfall and longer drought periods that reduce the efficacy of traditional farming practices (Kurniawati, 2012).

As climate change intensifies, the role of government becomes increasingly critical in mitigating its impacts on agriculture. The Indonesian government has responded by developing climate adaptation policies, particularly aimed at supporting the agricultural sector, which accounts for a significant portion of the country's economy and rural livelihoods. Government agricultural extension services, or Penyuluh Pertanian Lapangan (PPL)/ Agricultural Extension Officers, have been designed as a key mechanism to disseminate critical information on climate adaptation strategies, agricultural technologies, and sustainable farming practices (Harahap et al., 2019).

The success of these extension services, however, hinges on effective communication between the government and the farming communities they serve. According to the Diffusion of Innovation Theory by Rogers (2003), the adoption of new agricultural techniques, particularly those related to climate change adaptation, requires clear, consistent, and trusted communication channels. Agricultural extension officers (PPL) act as intermediaries between government research and local farming practices, playing a crucial role in introducing innovations and adaptation strategies to farmers. Unfortunately, studies have shown that Agricultural extension officers (PPL) services are often hindered by logistical challenges, such as limited manpower and geographic difficulties, particularly in remote highland areas like Dieng and Karo (Dewi et al., 2016). As a result, the advice provided is frequently too general or disconnected from the specific local contexts in which these farmers operate (Nwammuo & Nwafor, 2019).

In Dieng, for example, farmers have expressed frustration with the insufficient support they receive from government programs. Many rely on traditional knowledge and local practices to adapt to frost and water scarcity, while the government's communication and intervention efforts remain inconsistent (Mudasir, 2024). In the absence of targeted government initiatives, farmers in Dieng have resorted to using resources like Telaga Merdada, a local lake, for irrigation during the dry season. This, however, comes at a high operational cost, as farmers must invest in pumps and fuel to maintain water supply to their crops (Wonosobonews.com, 2024). Furthermore, competition for water with the expanding tourism industry has intensified resource scarcity, further complicating the situation for farmers (Lybbert & Sumner, 2009).

Similarly, in Karo, while digital platforms such as WhatsApp and Facebook have been employed to disseminate weather information and farming tips, farmers report that these efforts are insufficient for addressing the more profound challenges posed by climate change (Luthar, 2024). Farmers still face difficulties in accessing tailored training programs that provide comprehensive, long-term climate adaptation solutions. This reflects a broader challenge in government communication strategies, where information dissemination is often generic and fails to meet the specific needs of vulnerable farming communities (Harahap et al., 2019).

The lack of targeted and adaptive communication is one of the key factors that hinders the effective implementation of climate adaptation policies. Government programs often focus on broad agricultural practices without considering the unique environmental challenges faced by highland farmers. This has been emphasized in research by Dewi et al. (2016), which found that while Agricultural Extension Officerss were effective in improving productivity in some areas, their capacity to address climate-specific challenges, such as frost or water scarcity, was limited due to a lack of resources and specialized training.

Moreover, the expansion of non-agricultural industries in Dieng, such as tourism and geothermal energy projects, further exacerbates the challenges faced by farmers. These developments create additional pressure on local resources, particularly water, which is vital for both agricultural and tourism operations. The increasing demand for water from the tourism sector has led to conflicts over resource allocation, further marginalizing agricultural needs (Lybbert & Sumner, 2009). In this context, the government's role in balancing these competing interests becomes even more critical, requiring clear communication and stronger policy implementation to ensure that the agricultural sector remains sustainable.

Government communication, thus, plays a central role in shaping the resilience of the agricultural sector in the face of climate change. Effective communication of climate adaptation strategies not only requires the involvement of Agricultural Extension Officerss but also the integration of digital tools and localized, context-specific approaches that cater to the needs of highland farmers (Rogers, 2003; Tomaš Simin & Janković, 2014). As previous studies suggest, multi-channel communication strategies that combine in-person training with digital platforms could improve the adoption of innovative farming

techniques and help farmers better adapt to the rapidly changing environment (Lybbert & Sumner, 2009).

This study aims to explore the perceptions of farmers in Dieng and Karo regarding climate change and evaluate the effectiveness of government communication through Agricultural Extension Officer in facilitating climate adaptation. Through a series of interviews with farmers and Agricultural Extension Officerss, this research seeks to identify gaps in current government communication strategies and offer recommendations for improving the resilience of Indonesia's highland agricultural communities in the face of climate change.

LITERATURE REVIEW

Diffusion of Innovation Theory

The Diffusion of Innovation Theory (Rogers, 2003) provides a critical framework for understanding how new ideas and technologies, such as climate change adaptation strategies, are communicated and adopted within communities. This theory is particularly relevant in the agricultural context, where the success of new techniques depends heavily on how effectively they are communicated to and accepted by farmers. Rogers identifies five key stages in the diffusion process: knowledge, persuasion, decision, implementation, and confirmation. For Dieng's farmers, agricultural extension officers play a crucial role in initiating the knowledge phase, where farmers become aware of new strategies that could help them cope with the changing climate.

In rural settings like Dieng, the role of change agents—such as agricultural extension officers—becomes vital. These individuals act as intermediaries between research institutions, governments, and local farmers, helping to translate scientific innovations into practical knowledge that can be applied on the ground. However, for the diffusion process to be successful, the change agents must establish trust with the farmers, as well as ensure that the information provided is relevant and context-specific (Tomaš Simin & Janković, 2014).

In Dieng, where farmers like Agus and Komarun are experiencing increasing pressure from both climate change and resource competition, the dissemination of information through extension services is critical. Unfortunately, many farmers report that the information provided by extension officers is often too generic or insufficiently tailored to the specific challenges of their environment. This mirrors findings from other agricultural communities, where farmers are less likely to adopt new technologies or practices if they do not fully understand their benefits or if they perceive the information as coming from untrusted or distant sources (Agwu et al., 2018).

The situation in Dieng reflects a broader challenge seen in many developing countries, where Agricultural Extension Officerare often under-resourced, limiting their ability to effectively facilitate the diffusion of innovations. A study in Nigeria found that farmers were more likely to adopt improved agricultural technologies when these were communicated through multiple, trusted channels, including local community meetings, radio broadcasts, and face-to-face interactions with extension officers (Agwu, Ekwueme, & Anyanwu, 2018). This highlights the need for a more multifaceted approach to

communication in Dieng, where reliance on a single communication method may not reach all farmers effectively.

Government Communication and Agricultural Extension Services

The role of agricultural extension officers, also known as Penyuluh Pertanian Lapangan (PPL)/ Agricultural extension officers, is pivotal in disseminating information about climate change adaptation to farmers, particularly in rural regions where agriculture forms the economic backbone (Dewi et al., 2016). Rogers' Diffusion of Innovation Theory explains that for new farming techniques to be adopted, the communication between the government and farmers must be continuous, reliable, and persuasive (Rogers, 2003). Agricultural extension officers serve as the intermediaries in this process, ensuring that technical knowledge, such as water management or crop resilience, is accessible to the farming community (Simin & Janković, 2014).

In Indonesia, the agricultural sector faces additional challenges due to geographical limitations and resource constraints (Adib, 2014). The country's highlands, such as Dieng and Karo, are particularly vulnerable to climate variability, which complicates the role of Agricultural Extension Officerss (Lybbert & Sumner, 2009). The complex terrain makes frequent field visits difficult, further limiting the extension officers' ability to support farmers effectively. As a result, the communication process tends to be inconsistent and lacks the detailed, localized information farmers need for long-term adaptation to climate change (Harahap et al., 2019).

Table 1. Comparison Table: Government Approach and Innovation Adoption in Dieng and Karo

Aspect	Dieng (Central Java)	Karo (North Sumatra)
Government Communication Approach	Focuses on general agricultural advice through Farmer Field Schools (SL); limited climate-specific content; dependent on PPL/ Agricultural extension officers visits	Utilizes digital platforms (e.g., Facebook, WhatsApp) alongside field visits; slightly more integrated approach
Innovation Introduced	LAB and PGPR; frost protection advice	Same innovations, with additional focus on pest control and weather monitoring apps
Role of Agricultural Extension (PPL)	Led by figures like Sudi Purnomo; challenged by lack of climate-focused curriculum in Farmer Field School (SL) programs	Officers like Endang use both in-person and online channels; emphasize practical farming adaptations
Farmer Awareness Level	Generally aware of climate variability, but do not always link it to global climate change	Higher awareness due to exposure from mass media (TV, internet); better conceptual grasp
Adoption of Innovations	Partial and slow; hindered by limited technical support and unclear benefits	Moderate uptake; some farmers experiment based on media or peer learning
Communication Challenges	Geographic constraints; inconsistent information; limited persuasion phase	Limited government detail; over-reliance on external info sources (media, peers)
Policy Support Perception	Weak; absence of structured support for frost (bun upas) and water management	Similar perception; demand for clearer, more actionable government programs

Source: Researcher's data, 2024

Challenges in Climate Adaptation Communication

The limited success of Agricultural Extension Officerin conveying climate change adaptation strategies has been widely documented in various regions of Indonesia. Farmers often receive generic advice that does not adequately address the unique environmental and socioeconomic factors in highland areas like Dieng (Harahap et al., 2019). This mismatch between government programs and local needs highlights the need for more localized and context-specific strategies. According to Nwammuo and Nwafor (2019), the effectiveness of communication largely depends on the method used, with face-to-face communication being one of the most trusted by farmers. This has also been emphasized by Adib (2014), who pointed out that while digital tools like WhatsApp and Facebook have potential, they do not replace the need for personalized interactions with agricultural experts.

Policy-Driven Climate Adaptation Programs

The government's role in climate adaptation is crucial in developing countries like Indonesia, where the agricultural sector is highly vulnerable to extreme weather patterns. As Lybbert and Sumner (2009) highlighted, government policies must ensure that farmers have access to the necessary tools and technologies for climate resilience. However, in practice, government programs often fail to address specific challenges such as water management or frost protection in highland areas (Simin & Janković, 2014). This gap between policy and practical implementation creates a situation where farmers are left to rely on traditional knowledge or external information sources, such as weather apps or community networks.

METHODS

This study adopts a qualitative case study approach to explore how farmers in highland regions, specifically Dieng (Central Java) and Karo (North Sumatra), perceive and respond to the impacts of climate change, and to assess the effectiveness of government communication, particularly through agricultural extension officers (PPL), in facilitating adaptation. The research participants consisted of eight key informants, including six farmers and two agricultural extension officers. Participants were selected purposively based on their extensive experience in agriculture and direct exposure to issues such as frost, water scarcity, and shifting seasons. The extension officers were included to provide insight into government strategies and field-level implementation constraints.

Data were collected through in-depth, semi-structured interviews conducted in July and August 2024. The interviews were held at the participants' homes or farms to allow contextual observation and encourage open conversation. Each interview lasted approximately 40 to 60 minutes and focused on several themes, including the farmers' perceptions of climate variability, their strategies for managing water and frost risks, and their experiences with extension services. The research participants as follow:

1. Mudasir (50) – A potato farmer in the Dieng region, who has observed changes in climate and environmental conditions over the past decade. Mudasir highlights the

gaps in localized climate adaptation strategies and the convergence between traditional knowledge and government advice.

2. Agus (45) – A potato farmer from Karangtengah, Dieng Plateau, Central Java. Agus has been farming in the region for over two decades and has firsthand experience with water scarcity during the dry season, relying heavily on Telaga Merdada for irrigation.
3. Komarun (51) – Another farmer from Karangtengah, Dieng Plateau. Komarun's farm is located about 500 meters from Telaga Merdada, making him highly dependent on this water source during periods of drought. His experience provides key insights into the challenges of resource competition between tourism and agriculture.
4. Wahyu (40) – A potato farmer from Dieng Kulon, Central Java. Wahyu has experienced significant crop loss due to frost and extreme weather conditions in recent years, offering insights into the limitations of government support and agricultural extension services.
5. Nawan Sitepu (47) – A farmer from Kutarakyat, Karo, North Sumatra. Nawan shared that after receiving information from Agricultural Extension Officerss, he implemented innovative pest and disease control methods. However, he emphasized that information regarding climate adaptation policies from the government remains sparse and lacks detailed, actionable solutions.
6. Luthar Sembiring (47) – Another farmer from Kutarakyat, Karo, North Sumatra. Luthar mentioned that farmers often rely on discussions in local coffee shops to share insights and practices. He also pointed out that social media platforms, such as Facebook, are used by Agricultural Extension Officerss to communicate with farmers. Despite this, Luthar expressed the need for more substantial, practical training on climate adaptation strategies.
7. Sudi Purnomo – The Coordinator of Agricultural Extension Officers (Penyuluh Pertanian Lapangan) for Batur Subdistrict, Banjarnegara, Central Java, under the Department of Agriculture, Fisheries, and Food Security. As a representative of the government's agricultural extension services, Sudi provides critical insights into the logistical and policy challenges faced in disseminating climate adaptation strategies to farmers. His role highlights the practical constraints extension officers encounter, such as limited manpower and the vast geographic area they cover.
8. Endang Dani Aty Br Bukit – An agricultural extension officer (Penyuluh Pertanian Lapangan or PPL) from Karo, North Sumatra, who provides insights into the government's role in communicating climate adaptation strategies to farmers. Her experiences underscore the logistical and policy-related challenges faced by Agricultural Extension Officerin highland regions.

To complement these qualitative findings, a small-scale perception survey involving 51 respondents was also conducted to capture broader trends. The survey included Likert-scale items designed to assess awareness of seasonal shifts and the perceived impact of climate change on agricultural productivity. The interview data were

analyzed using thematic analysis. After transcribing and familiarizing with the data, the researcher identified key codes such as “water scarcity,” “uncertain rainfall,” “government support,” and “traditional adaptation.” These codes were then grouped into broader themes that reflected the core issues faced by farmers. Survey data were analyzed descriptively and used primarily to support qualitative findings, particularly in visualizing how widespread certain perceptions were among farmers in the two regions. By combining interview insights and basic quantitative trends, this study provides a nuanced understanding of how innovation diffuses—or fails to diffuse—through government communication in highland agricultural communities.

RESULTS AND DISCUSSION

Farmers’ Perceptions of Climate Change

Farmers in both Dieng and Karo highlands have become increasingly aware of the impacts of climate change—especially in the form of shifting seasons, unpredictable rainfall, more frequent frost, and prolonged droughts. According to field interviews and survey data, many farmers agree that changing seasonal patterns are part of broader climate change phenomena, although they often lack access to in-depth information about the causes and solutions.

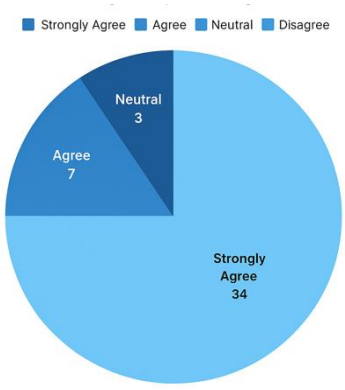

Figure 1. Farmers’ Perception on Seasonal Shifts as Climate Change Indicators (Source: Researcher’s Survey Data, 2024)

One of the most common concerns shared by farmers is the disruption of planting cycles, which were previously based on traditional systems such as *Pranatamangsa* in Dieng. Nowadays, unexpected rainfall or dry spells have made it difficult for farmers to plan and execute planting and harvesting on time, leading to lower yields and market losses. As shown in Figure 1, a majority of respondents either “agree” or “strongly agree” that unpredictable seasons are a result of climate change.

Farmers also report that over the past ten years; they have observed increasingly erratic weather patterns. In Dieng, bun upas (frost) now occurs outside the expected dry season, destroying potato crops. In Karo, shortened rainy seasons combined with longer dry spells have led to water scarcity, particularly affecting rain-fed agriculture. Furthermore, farmers understand that climate change has a direct impact on yields—through pest outbreaks, irregular flowering cycles, and smaller produce sizes. For example, potato farmers in Dieng mentioned increased pest infestations, while vegetable farmers in

Karo reported reduced productivity due to excessive heat during the vegetative stage. Although their experiential knowledge is strong, most farmers still lack structured, science-based guidance from the government, and depend on personal experience, media, and peer discussions for information.

Government Communication and the Early Phases of Innovation Diffusion

The findings from the interviews revealed significant gaps in the communication between the government, particularly through agricultural extension officers (PPL), and the farmers in Dieng and Karo. Despite efforts by extension officers like Sudi Purnomo, the coordinator of Agricultural extension officers (PPL) for Batur Subdistrict, Banjarnegara, farmers feel that the advice they receive is too generalized and does not specifically address the local challenges brought on by climate change. This is consistent with Rogers' (2003) Diffusion of Innovation Theory, which suggests that for new agricultural practices to be effectively adopted, communication must be personalized and consistent, ensuring that farmers are fully persuaded of the innovation's relevance and benefits.

Farmer Field Schools (SL), have been one of the key initiatives led by Agricultural Extension Officerss to provide hands-on, community-based learning for farmers. According to Sudi Purnomo, the Farmer Field School (SL) program offers farmers practical training in real-time, seasonal conditions. “Through Farmer Field School (SL), we bring together farmers to learn directly in the field, adapting to real weather and crop conditions, but it’s still a challenge to address specific climate change issues,” he remarked during an interview (Interview, 2024).

Figure 2. Thematic Farmer Field School (SL) for Potatoes by Agricultural Extension Officers
(Source: Primary Data from Informants, 2024)

However, Sudi noted that while Farmer Field School (SL) provides valuable knowledge on general agricultural techniques, the curriculum has not yet fully incorporated detailed climate adaptation strategies.

In Dieng, farmers like Mudasir exhibit an understanding of unpredictable weather but do not necessarily associate this with global climate change. According to Mudasir, “In the past, the rainy season was more predictable, but now suddenly there can be a long dry season when it should be raining.” (Interview, 2024). This reflects the knowledge phase of the Diffusion of Innovation Theory, where farmers become aware of climate-related

changes but may not yet fully comprehend their implications or solutions. Mudasir's statement underscores the limited understanding of broader climate phenomena, which could be attributed to a lack of targeted information and communication strategies.

In contrast, Nawan Sitepu, a farmer from Karo, demonstrated a higher awareness of climate change, attributing much of his knowledge to mass media sources like TV and the internet. However, he also pointed out the lack of actionable advice from the government, saying, “We often hear about climate change from TV or the internet, but there is no specific information from the government on what we can do” (Interview, 2024). This mirrors findings from Lybbert and Sumner (2009), who emphasize that while exposure to climate-related information may be high, the absence of concrete guidance leaves farmers unsure of how to adapt their practices.

The persuasion phase of the Diffusion of Innovation Theory is critical in such cases. According to Rogers (2003), for farmers to adopt new practices, they must be persuaded of the innovation's benefits through trusted channels. In both Dieng and Karo, Sudi Purnomo and Endang acknowledged the limitations of their roles as agricultural extension officers. As Sudi mentioned, “We don't have specific programs from the department for climate change, we usually just share information about crop management during the rainy and dry seasons.” (Interview, 2024). This points to a crucial gap in the persuasion phase, as farmers are not receiving the necessary, tailored information that would convince them to adopt new, climate-resilient practices.

While Farmer Field School (SL) programs in area like Batur help provide basic agricultural knowledge, Sudi emphasized the need for Farmer Field School (SL) curricula to integrate climate resilience practices. “Farmer Field School (SL) provides a good base for community learning, but the challenge now is ensuring that climate change adaptation is a part of these trainings,” he said (Interview, 2024). Agwu et al. (2018) support the idea that localized, specific guidance is necessary for farmers to adopt resilient practices.

The findings from Dieng and Karo highlight the communication barriers in place, where government programs lack specificity and do not offer comprehensive solutions for water management, frost prevention, or crop adaptation. This is particularly problematic in areas like Dieng, where farmers such as Wahyu are struggling with frost events like bun upas, a phenomenon that can devastate crops overnight. Wahyu shared, “When the frost (bun upas) comes, the plants can die in a single night.” (Interview, 2024). The lack of structured government programs to address such risks leaves farmers reliant on traditional, often inadequate, methods of protection.

Farmer Initiatives and Community-Based Adaptation

Despite the challenges, there are examples of local initiatives and community-based adaptations to climate variability. Both Agus and Komarun mentioned that they have started to shift their planting schedules in response to changing weather patterns, such as waiting for the rainy season to begin before planting their crops. This adaptation strategy, while informal, has helped them mitigate the effects of drought and erratic rainfall (Interview with Agus, 2024). However, these efforts are limited by a lack of broader institutional support and access to modern technologies that could further improve resilience.

One of the topics covered in the Farmer Field School (SL) is the cultivation of lactic acid bacteria (LAB). LAB culture is an important adaptation technique that reduces farmers' reliance on chemical fertilizers and pesticides, while enhancing soil health and microbial activity. By encouraging these sustainable practices, the Farmer Field School (SL) program provides farmers with tools to adapt to climate change while also contributing to broader efforts to mitigate its effects by lowering greenhouse gas emissions and promoting carbon sequestration.

In addition, the use of PGPR is another key element introduced by extension officers to help farmers combat the climate crisis. PGPR enhances plant growth by improving nutrient uptake and increasing resistance to environmental stressors, such as drought and soil degradation—both of which are exacerbated by climate change. By reducing the need for chemical fertilizers and pesticides, PGPR helps lower greenhouse gas emissions associated with their production and use. This practice also improves soil health and biodiversity, contributing to more resilient agricultural systems that can better withstand the unpredictable weather patterns brought on by climate change. As Sudi Purnomo emphasized, “We encourage farmers to use natural solutions like PGPR, which not only improve crop productivity but also reduce the environmental footprint of farming” (Interview with Sudi Purnomo, 2024). Integrating PGPR into farming practices plays a key role in reducing agriculture’s environmental impact and fostering climate adaptation.

Figure 3. Farmer Field School (FFS) Practice
(Source: Primary Data from Informants, 2024)

Luthar Sembiring, a farmer from Karo, mentioned that farmers in his area have begun to share information informally through daily discussions at local coffee shops, where they exchange tips and strategies on how to cope with changing weather patterns (Interview with Luthar, 2024). This community-driven approach to knowledge sharing is crucial in the absence of formal government programs. As noted by Ingram, Roncoli, and Kirshen (2012), localized knowledge-sharing networks can play a vital role in helping communities adapt to climate variability, particularly when formal support structures are lacking. In these discussions, the role of the Farmer Field School (SL) program in disseminating practical, climate-resilient farming techniques, such as LAB culture, is frequently highlighted as a key strategy to build local resilience. The inclusion of PGPR in these grassroots exchanges, alongside Farmer Field School (SL)’s technical support,

demonstrates the power of combining traditional and modernknowledge in addressing climate challenges.

Figure 4. Discussion between Extension Officers and Farmers in Karo
(Source: Primary Data from Informants, 2024)

Water Scarcity and Management Challenges

Water scarcity is a critical issue affecting farmers in both Dieng and Karo. In Dieng, Agus, a potato farmer, explained the challenges he faced during the dry season: "We rely on using pumps to get water from Telaga Merdada. Every day, we need 10 to 11 liters of gasoline just to run the pump." (Interview, 2024). This aligns with Rogers' Implementation phase, where farmers attempt to apply new practices but face financial or logistical barriers that hinder successful adoption. While Agus has adapted by using water pumps, the absence of institutional support for sustainable water management makes this solution financially unsustainable in the long term. Agus's reliance on gasoline-powered pumps to transport water from the lake reflects the increasing competition for water resources in Dieng, where tourism and geothermal energy projects have placed additional pressure on the region's natural water sources (Wonosobonews, 2024).

Komarun, another farmer from Dieng, noted that without access to water from Telaga Merdada, his crops would not survive the dry season. "The water from the lake is very important, especially during long dry seasons. We have no other choice but to pump water from there. The costs are high, but if we don't water the plants, they will die." (Interview, 2024). This illustrates the significant financial burden placed on farmers due to water scarcity, as they are forced to invest in equipment and fuel to maintain their crops. These challenges are compounded by the lack of government programs aimed at improving water management infrastructure for farmers, a gap that was also noted by Endang, an agricultural extension officer from Karo. Endang remarked, "There are no programs for water management or climate adaptation yet. We can only share basic information about water management during the dry and rainy seasons." (Interview, 2024).

In Karo, farmers have developed more localized water management practices, such as rainwater harvesting, but these systems remain rudimentary. Luthar Sembiring, a farmer from Karo, explained that "Sometimes we collect rainwater, but it's only enough for daily use, not for agricultural needs during long dry seasons." (Interview, 2024). This reflects the trial phase of the Diffusion of Innovation Theory, where farmers experiment with new practices but may not see widespread adoption due to lack of resources or adequate

infrastructure. This highlights the need for more government support to enhance water management practices, particularly as climate change leads to longer dry seasons and increased competition for water resources.

Research by Lybbert and Sumner (2012) supports these findings, emphasizing the importance of government involvement in improving water management infrastructure in agricultural regions facing climate variability. Without adequate support, farmers are forced to rely on expensive, unsustainable practices such as gasoline-powered pumps, which may not be viable in the long term. The government's role in this regard is crucial, as effective water management systems could help farmers mitigate the effects of climate change and reduce their financial burden.

Frost Prevention and Crop Protection

Frost events, such as the phenomenon known as "bun upas," are a major concern for potato farmers in Dieng. Wahyu, a farmer from Dieng Kulon, described the devastating impact of frost on his crops: "When the frost comes, the plants can die overnight. Last year, many of my neighbors' potato plants died because of the frost." (Interview, 2024). Wahyu's experience reflects the extreme vulnerability of highland farming communities to frost, particularly during the dry season when crops are most susceptible to cold temperatures.

Farmers attempt to mitigate the effects of frost by covering their crops with plastic sheeting, but this strategy is not always effective. Nuryadi, a farmer living near geothermal wells in Dieng, noted that "We usually cover the plants with plastic, but if the frost comes too early, the plants can still get damaged." (Interview, 2024). This further supports Rogers' Decision phase, where farmers must decide whether to continue using traditional methods or adopt new innovations. However, in the absence of government-supported frost prevention strategies, farmers are left without viable alternatives. This highlights the limitations of current frost prevention strategies, which rely on traditional methods rather than modern technologies that could offer better protection.

In Karo, farmers also face challenges related to erratic weather patterns, although they have developed more sophisticated strategies for managing frost risk. Nawan Sitepu explained that "We often adjust the planting schedule based on weather forecasts, but sometimes there are still unexpected weather events that we can't predict." (Interview, 2024). This suggests that while farmers in Karo are more proactive in adjusting their farming practices based on weather forecasts, they still face significant challenges due to the unpredictability of climate change.

The lack of structured government programs to help farmers manage frost risk was noted by both Sudi and Endang, who admitted that their role as agricultural extension officers was limited to providing basic crop management information. According to Sudi, "We don't have a specific program to deal with frost or climate change, but we try to help by sharing information on how to care for the crops." (Interview, 2024). This reflects a broader issue in many developing countries, where Agricultural Extension Officerare underfunded and unable to provide the level of support needed to address the specific challenges of climate change (Tomaš Simin & Janković, 2014).

Diffusion of Innovation Context

To understand the diffusion of innovation in the context of agricultural adaptation to climate change, it is important to first define the specific innovations addressed in this study. These include the application of LAB and PGPR as environmentally friendly agricultural solutions. These innovations have been promoted through the Farmer Field School (SL) program led by agricultural extension officers (PPL) since approximately 2022 in the Batur region of Dieng and parts of Karo. The Farmer Field School (SL) program serves as the primary communication channel employed by local governments, particularly through the Agricultural Office, to disseminate innovations related to climate change adaptation.

In the framework of Diffusion of Innovations Theory (Rogers, 2003), the stages observed in the field include:

1. Knowledge Stage: Farmers are becoming aware of climate change and adaptive solutions such as LAB and PGPR. However, much of this information is acquired through mass media (e.g., television or the internet) or informal peer discussions rather than through official institutional channels.
2. Persuasion Stage: While the Farmer Field School (SL) program provides field-based training, persuasion remains limited due to constraints in content depth and resources. Many farmers still do not fully grasp the direct benefits of the innovations offered.
3. Decision Stage: Some farmers, such as Agus and Komarun, have begun to experiment with these innovations on a limited scale. However, broader decision-making has yet to take place due to the absence of concrete incentives and consistent technical support.
4. Implementation Stage: Practices such as the use of PGPR and LAB are being adopted incrementally. Nevertheless, challenges related to cost, access, and infrastructure hinder their widespread implementation.
5. Confirmation Stage: Due to the limited follow-up and evaluation from governmental institutions, many farmers remain uncertain about the long-term effectiveness of these innovations—particularly in addressing climate-specific threats such as frost (bun upas) and prolonged droughts.

The primary actors driving this process are extension officers such as Sudi Purnomo and Endang, who operate under the supervision of the local agricultural departments. However, the limited number of officers and the wide geographic coverage required have led to an uneven diffusion of these innovations.

Thus far, the outcomes of this innovation process are mostly restricted to raising awareness and initiating small-scale field trials among a minority of farmers. Widespread behavioral shifts in adaptive farming practices remain limited, especially at the persuasion and confirmation stages, highlighting the need for stronger communication efforts and institutional support.

Barriers and Opportunities in Government Communication for Climate Adaptation

The interviews with farmers and agricultural extension officers (PPL) revealed a clear gap between government climate adaptation policies and the actual support provided

to farmers. Endang, a Agricultural Extension Officers from Karo, mentioned that while she shares information on crop management based on seasonal changes, there are no government programs specifically targeting climate change adaptation. “There is no specific government program for climate change adaptation yet, only basic information that we share,” she noted (Interview, 2024). This reflects a significant gap in the confirmation phase of the Diffusion of Innovation Theory, where farmers are not provided with the necessary follow-up support to confirm their decision to adopt new practices.

Farmers like Slamet and Wahyu echoed this frustration, pointing out the lack of concrete guidance from government officials. Wahyu emphasized, “The extension officers sometimes come, but the information they provide is still too general. We need more concrete solutions, especially regarding water management and crop protection from frost.” (Interview with Wahyu, 2024). This reflects a broader challenge in Indonesia’s agricultural sector, where government policies tend to be reactive rather than proactive, leaving farmers to rely on their own traditional knowledge or external information sources (Harahap et al., 2019). Research by Agwu et al. (2018) supports this, showing that farmers in developing countries are more likely to adopt resilient practices when government programs provide tailored, localized guidance. Rogers' Theory suggests that for innovations to be widely adopted, continuous support and tailored advice are essential, especially in the confirmation phase, where farmers need reassurance that their decision to adopt new practices will yield positive results.

Agus, another farmer, emphasized the critical but often insufficient role of Agricultural Extension Officerss in disseminating climate-related information. Although Agricultural Extension Officerss visit, the frequency is low and the advice provided lacks actionable specifics. According to Rogers' Diffusion of Innovation Theory (2003), for farmers to effectively adopt new practices, consistent, personalized communication from trusted sources is essential. However, in regions like Dieng and Karo, many farmers feel that the support from Agricultural Extension Officerss does not meet their unique needs. This challenge is further complicated by logistical issues, such as limited manpower and the wide geographic areas that Agricultural Extension Officerss need to cover. As Sudi stated, “Our team is small, and the area we cover is large, so many farmers don’t get the help they need” (Interview with Sudi, 2024). Similar constraints are observed by Nwammuo and Nwafor (2019), who found that under-resourced extension services often fail to meet the specific needs of farmers in developing countries.

Interestingly, the interviews revealed a slightly more optimistic perspective from farmers in Karo, where communication between Agricultural Extension Officerss and farmers includes regular updates on weather and farming advice through Facebook and WhatsApp groups. Luthar, a farmer in Karo, explained that while these digital platforms are helpful, there remains a strong need for comprehensive training, particularly regarding long-term strategies for climate adaptation (Harahap et al., 2019). Lybbert and Sumner (2009) support the use of multifaceted communication approaches, combining digital platforms with face-to-face interactions, a model that has been successful in other regions, such as sub-Saharan Africa, and could potentially be applied in Indonesia.

However, the interviews underscore a significant gap between the current government efforts and the actual needs of farmers for climate adaptation support. Mudasir, a farmer, pointed out that the advice provided by government extension officers often focuses only on basic crop management and neglects broader issues of climate variability. He stated, “While the officers visit farms, the guidance is too general and does not address the specific challenges faced in our local environment” (Interview with Mudasir, 2024). This concern aligns with Rogers' (2003) argument that the success of agricultural innovations heavily depends on how well they are communicated and adapted to specific local contexts.

Endang, the Agricultural Extension Officers, confirmed that while there are some training programs available, these are infrequent and often do not emphasize climate resilience. She stressed the importance of developing more targeted, localized training programs that address the distinct challenges faced by highland farmers, such as those in Dieng and Karo (Interview with Endang, 2024). This point is supported by Tomaš Simin and Janković (2014), who highlight the critical role of context-specific training and extension officers in facilitating the diffusion of climate adaptation innovations.

Recommendations for Policy Improvement

Based on the interviews and literature reviewed, it is clear that there is a need for more comprehensive, targeted government programs to address the challenges posed by climate variability in highland farming areas. The current efforts, while valuable, are insufficient to meet the complex needs of farmers who are increasingly facing unpredictable weather and resource competition from other industries such as tourism. As suggested by the interviews with Sudi and Endang, there needs to be a greater emphasis on climate-resilient farming practices, with more frequent and specialized training sessions for farmers. The government should also consider implementing more robust water management policies to ensure the equitable distribution of water resources between agriculture and tourism. As the demand for water increases, it will be critical to prioritize the needs of local farmers to ensure the sustainability of the region’s agricultural economy.

CONCLUSION

The findings from this study highlight the complex and interwoven challenges faced by farmers in Dieng and Karo as they attempt to adapt to the effects of climate change. While agricultural extension officers play a crucial role in disseminating information, the support provided by government programs is often too general to address the specific challenges faced by highland farmers. This lack of targeted communication leaves farmers to rely on traditional knowledge and informal networks, which may not be sufficient to cope with the increasing unpredictability of weather patterns, water scarcity, and frost events. To improve the effectiveness of climate adaptation strategies, the Indonesian government must invest in more structured and region-specific communication programs. Agricultural Extension Officermust be adequately resourced and trained to offer practical, actionable advice on water management, frost prevention, and other climate adaptation strategies. By doing so, the government can better support farmers in adapting

to the changing climate and ensuring the long-term sustainability of agriculture in highland regions.

This study highlights the need for more localized and targeted government communication in delivering climate adaptation strategies to highland farmers. It shows that without personalized and consistent support, innovations like PGPR or LAB are unlikely to be widely adopted. The findings also reaffirm Rogers' Diffusion of Innovation Theory, especially the importance of the knowledge, persuasion, and confirmation stages. Practically, agricultural extension programs such as Farmer Field Schools (SL) should integrate climate resilience content, while communication strategies must combine face-to-face methods with digital tools to reach more farmers effectively.

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