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Climate-Smart Rice Production in Thailand: Challenge and Opportunity

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Abstract

Rice, a staple diet for over half the global population, with over eighty percent of production concentrated in Asia, faces significant challenges from climate change, particularly in Thailand. This review analyzes the current situation of rice production in Thailand, its contribution to Greenhouse Gas (GHG) emissions, and the impacts of climate change on productivity, drawing insights from existing literature. Findings indicate that Thailand's rice production has gradually declined, potentially affecting global food security through reduced exports. Thai farmers contend with rising temperatures, erratic rainfall, and extreme weather events, which heighten production risks and disrupt planting schedules, especially for rain-fed systems. Additionally, rice cultivation is a notable source of GHG emissions, releasing methane (CH_4) and Nitrous Oxide (N_2O) under flooded conditions, which favor anaerobic decomposition. To mitigate these circumstances, Climate-Smart Agriculture (CSA) practices are being widely introduced as a holistic approach. Common strategies observed across Vietnam, Malaysia, and Thailand include Alternate Wetting and Drying (AWD) and the use of climate-tolerant rice varieties, which help mitigate water scarcity and extreme climate conditions. The review emphasizes, however, that the selection of appropriate CSA practices must consider diverse regional and local contexts. To facilitate broader CSA adoption and enhance climate resilience, this review recommends further research into high-potential microorganisms for efficient rice straw decomposition and addressing the scarcity of skilled service providers and machinery for Laser Land leveling. Ultimately, adopting climate-smart rice production will enable Thai farmers to adapt to sustainable practices and enhance their global competitiveness in the rice market.

Keywords: Rice Production, Climate Change, Climate Smart Agriculture

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Introduction

Rice is a staple grain that feeds more than half of the world's population and is cultivated in over one hundred countries globally (Fukawa & Ziska, 2019). According to 2024/2025 United States Department of Agriculture (USDA) reports, global rice production was 532.7 million tons, with over eighty percent originating from nine Asian countries: China, India, Bangladesh, Indonesia, Vietnam, Thailand, the Philippines, Burma, and Pakistan (USDA, n.d.). This concentration means the stability of global food security largely relies on rice production in the Asia region (Bandumula, 2018).

However, food security currently faces severe threats, prominently climate change. Farmers worldwide are grappling with rising temperatures, erratic rainfall patterns, and increased frequencies of extreme weather events, all of which directly impact crop growth cycles and rice yields. For Thailand, a leading rice producer and exporter, these climate-induced disruptions pose a critical threat not only to its national economy and farmer livelihoods but also to its pivotal role in global food supply chains. With the United Nations projecting the global population to reach 9.7 billion by 2050 (Food and Agriculture Organization of the United Nations [FAO], 2018) and total food demand expected to increase by 35% to 56% between 2010 and 2050 (van Dijk et al., 2021), ensuring access to sufficient and nutritious food requires farmers to urgently adapt to fluctuating weather, extreme temperatures, drought, and heavy rainfall. This necessitates a proactive and robust approach to agricultural development.

CSA, introduced by the FAO has gained widespread recognition and is being broadly implemented to mitigate climate change impacts. Governments and international organizations in Asian countries, including Vietnam (Tran et al., 2020; Luu, 2020; Duc Truong et al., 2022) and Thailand (Khamkhunmuang et al., 2022), are applying various CSA practices to boost rice productivity while reducing GHG emissions. For Thailand, methane (CH_4) from rice cultivation accounts for 40% of emissions in the agriculture sector (The Nation, 2025). Therefore, the environmental impact of GHG emissions, particularly from agriculture, has emerged as a critical national concern. Given Thailand's significant global role and particular vulnerability to climate shifts, effectively addressing existing obstacles and capitalizing on emerging opportunities to enhance climate-smart rice production is paramount for its agricultural resilience and global competitiveness.

Against this critical backdrop, the first aim of this review study is to focus on the current situation and effects of climate change on rice production in Thailand. Secondly, we summarize CSA practices and technologies in Vietnam, Malaysia, and Thailand to provide a clear understanding of their achievements. Finally, we will outline the challenges and future opportunities to enhance CSA for rice production in Thailand, highlighting areas for strategic intervention.

Content

Current Situation of Rice Production in Thailand

Rice has been cultivated in Thailand for many thousands of years and serves as the foundation of both food security and economic stability (Castillo, 2011). Initially, most of the rice production in Thailand highlighted the significance of smallholder farming systems where family labor and conventional methods were dominantly applied. An objective of rice production in Thailand was for self-consumption in farmer households and exchanging with other goods in the local community (Buddhaboon et al., 2022). Since 1976, or the fourth National Economic and Social Development Plan (NESDP), the Thai government has understood that further expansion of farmland would not be a mere answer for increasing agricultural production. Thus, the government decided to start a new program to elevate agricultural production by introducing modern agricultural technologies such as High-Yield Varieties (HYV) seed, modern farm machinery, fertilizer, and pesticides (Thepent & Chamsing, n.d.). Therefore, these efforts resulted in a significant increase in production capacity.

While existing literature offers extensive documentation on Thailand's general rice production trends and the broad impacts of climate change, this review provides a crucial, updated synthesis. It uniquely positions the current challenges within the evolving landscape of CSA strategies adopted across major Southeast Asian rice-producing nations, thereby highlighting specific, actionable insights and opportunities for enhancing Thailand's rice sector's resilience and competitiveness.

The Rice production system in Thailand can be categorized into wet and dry seasons. The rice cultivation area is about 10 million hectares annually. Rice production in the wet and dry seasons accounts for 82% and 18% of annual production, respectively, as shown in Figure 1. Rice production is dominant in northern and northeastern regions in the wet season, while most of the rice production is from the central region. In terms of ecosystem alignment, rice production areas can also be classified from upstream to downstream into upland rice, rain-fed rice, irrigated rice, and deep-water and floating rice production systems, as shown in Figure 2. Rain-fed rice and irrigated rice are the most important rice-growing systems in Thailand. The cultivation areas are about 75% and 24% of the total rice-growing area, respectively (Buddhaboon et al., 2022). Rain-fed rice is usually grown once per year in the wet season when Monsoon rain is the sole source of water supply for rain-fed rice cultivation (FAO, 2000). As an irrigated rice cultivation, it can grow in both wet and dry seasons under the availability of an irrigation water supply. The rice production in Thailand in 2013 was approximately 36.7 million tons and declined to 33.1 million tons in 2023 (FAO, 2025). The decline in rice production would affect global food security, according to the decrease in the amount of rice that is exported from Thailand.

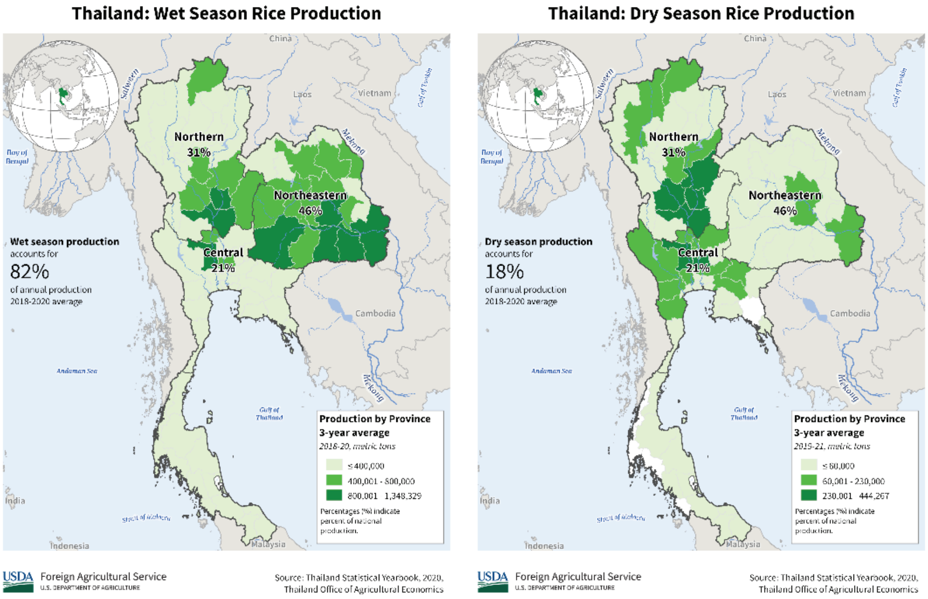

Figure 1 Rice Production in Wet and Dry Seasons in 2020

Source: USDA (2020)

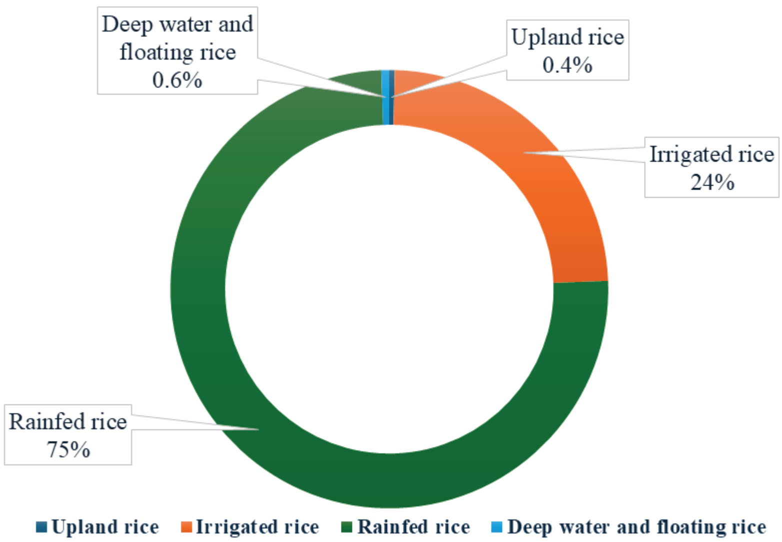

Figure 2 Percentage of Area of Rice Cultivation in Thailand

Source: Modified from Buddhaboon et al., 2022

Climate Change and Rice Production in Thailand

Climate change is one of the various causes that affect the yield of rice production in Thailand. Farmers are facing rising temperatures, changes in rainfall patterns, and extreme weather phenomena. As of 2016, 354 $MtCO_2$ were emitted from Thailand. The greatest proportion of GHG emissions was from the energy sector, which accounted for 71.65% of total emissions, followed by the agricultural sector, which accounted for 14.72%, as shown in Figure 3.

The agricultural sector was the second greatest contributor of total GHG emissions in Thailand, whit 52 MtCO_2 of GHG emissions emitted from farm activities. From total GHG emissions in the agricultural sector in Thailand, rice cultivation was the biggest contributor to total GHG emissions. It shared about 51% at 27 MtCO_2 of GHG emissions, as shown in Figure 4.

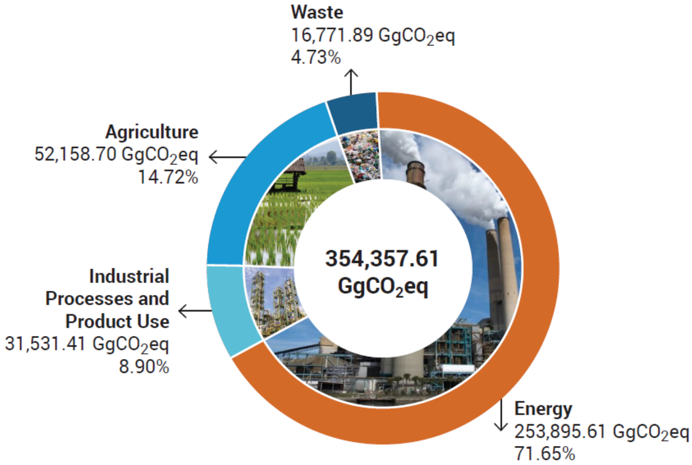

Figure 3 Total GHG Emissions from Different Sectors in Thailand

Source: Office of Natural Resource and Environmental Policy and Planning, 2020

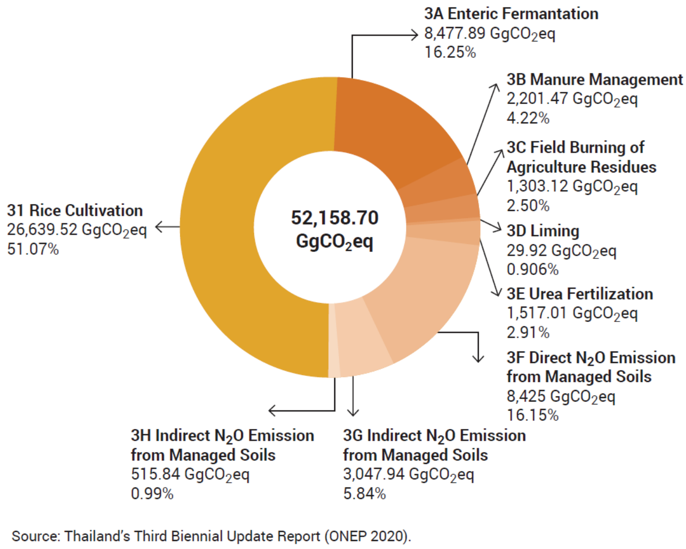

Figure 4 GHG Emissions in Agricultural Sectors in Thailand

Source: Office of Natural Resource and Environmental Policy and Planning, 2020

Rice has become one of the greatest GHG emission contributors in the agricultural sector. It is a concern due to the farm practices by the farmers could emit potent GHG emissions such as methane (CH_4) and Nitrous Oxide (N_2O). During the flooding period of rice production, methane could be produced from organic matter in the soil, such as organic fertilizers, root exudates, plant residues, and weed residues under anaerobic conditions (Rajendran et al. 2024). Besides GHG emissions, the temperature has increased across Thailand. The annual mean temperature in Thailand also rose by approximately 1˚C from 1981 to 2020, as shown in Figure 5. A great

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temperature fluctuation has been observed since 1996. For the annual mean rainfall in Thailand during 1952-2019, it was around 1400-1900 mm, as shown in Figure 6. The annual mean rainfall during 1977-1993 displayed the tendency that the amount of rainfall was continuously below the normal baseline, as shown in Figure 7.

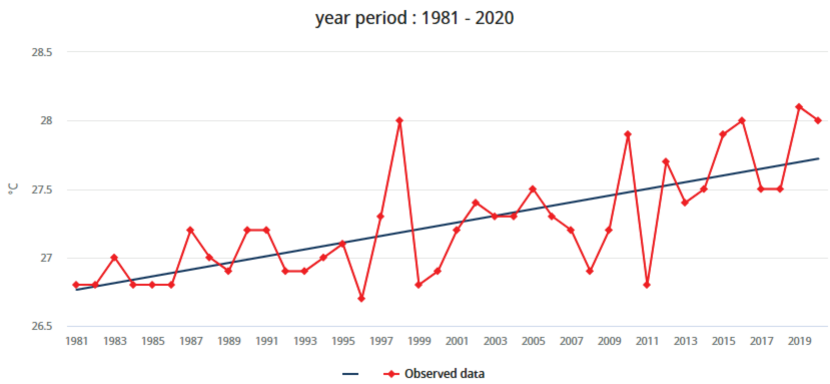

Figure 5 Annual Mean Temperatures in Thailand

Source: Thai Meteorological Department, 2022

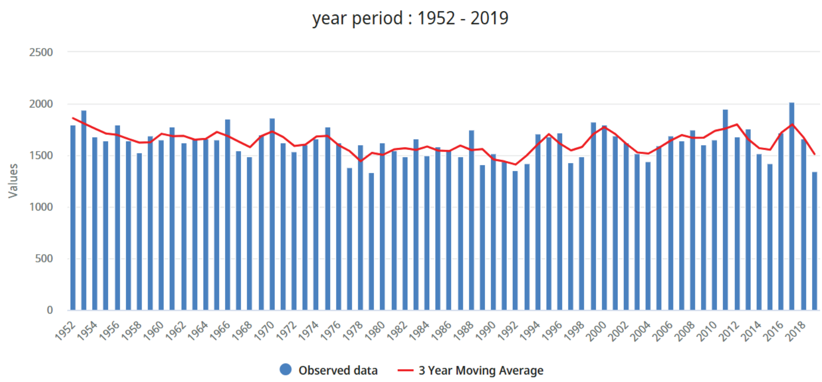

Figure 6 Annual Mean Rainfall in Thailand (mm)

Source: Thai Meteorological Department, 2022

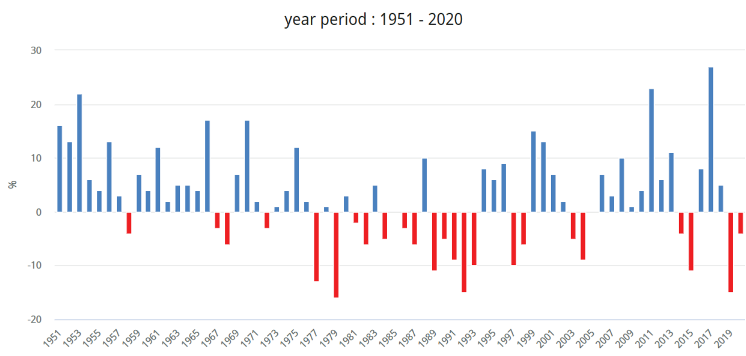

Figure 7 Percentage of Annual Rainfall Differed from Normal Rainfall in Thailand during 1951-2022

Source: Thai Meteorological Department, 2022

Since the temperature tends to increase while the rainfall is below the normal baseline and follows severe drought conditions. Therefore, rain-fed rice growers would be the ones who suffer the most from insufficient rainfall. Moreover, the drought may affect the irrigated rice farmers' farm practices by delaying their planting period (Phuong, 2016). The risk of rice production is also higher when the temperature increases. Pakeechai et al. (2020) noted that the risk of rice production will increase by 52.8% in the central region of Thailand when the temperature increases by 1%. Attavanich (2023) estimated the results of climate change in rice production, especially that the total yield of rice and total rice harvested area were projected to decrease around 10.3-14.4% and 0.2-1.3%, respectively. This may lead to a decrease in the production of rain-fed rice and irrigated rice from the baseline around 25.7-34.6% and 10.2-13.3%, respectively.

Climate Smart Agriculture in Rice Production

CSA is a holistic approach to assist farmers in adapting their farm practices and surviving the effects of climate change. CSA was initially introduced at the 2010 Hague Conference on Agriculture, Food Security, and Climate Change.

CSA is an approach that directs the farmers about the actions that need to be done for transforming and reorienting agricultural production systems and food value chains to ensure food security in a changing climate (FAO, 2013). The aims of CSA are described by Sebastian and Bernardo (2019) as follows:

1. Sustainable increase in agricultural productivity and incomes
2. Adapt and build resilience to climate change
3. reduce and or remove greenhouse gas emissions

To implement Climate-Smart Rice (CSR) for the farmers, there are many crucial aspects, including water-smart, nutrient-smart, carbon-smart, energy-smart, weather, and knowledge-smart, as shown in Table 1 (Das et al., 2024).

Table 1 Key Dimensions of Climate-Smart Rice

Key Dimensions	Examples
Water Smart	- Alternate Wetting and Drying (AWD) - Weather prediction-based irrigation
Nutrient Smart	- 4R concept (right time, right rate, right source, and right place) - Slow-release nitrogen fertilizer application - Sub-surface nitrogen fertilizer application - Real-time and site-specific nutrient management
Carbon Smart	- Residue incorporation and retention - Biochar application - Zero tillage or minimum tillage
Energy Smart	- Zero tillage or minimum tillage - Direct-seeded rice - Laser soil levelling

Table 1 Key Dimensions of Climate-Smart Rice (Con.)

Key Dimensions	Examples
Weather Smart	- Weather forecasts - Weather-based crop agro-advisory - Stress-tolerant crops
Knowledge Smart	- Precision farming - Crop insurance

Rice was recognized early on as a key sector for CSA practices due to its significant contribution to greenhouse gas emissions. The Global Alliance for Climate-Smart Agriculture (GACSA) was established in 2014 to promote CSA globally, including in rice production systems (FAO, 2021). Implementation of CSA in rice production involves adopting practices that enhance productivity, strengthen resilience to climate change and reduce greenhouse gas emissions. Practical experiences in Asia and Africa indicate that CSA practices in rice farming have generated tangible gains in both productivity and environmental outcomes, paving the way for a shift toward more climate-resilient agricultural systems (Bhusal et al., 2025; Khamkhunmuang et al., 2022; Sanago et al., 2023).

Considering these key dimensions could be implemented to secure rice production, there are also some more concerns that farmers need to take into consideration. Since each farmland or rice field is quite different, farmers need to consider which technique or method is suitable for their rice production. As shown in Table 2, the CSA practices and their impact on rice production in Vietnam, Malaysia, and Thailand were summarized.

Table 2 CSA Practice and Impact on Rice Production

Country	CSA Practice	Impact on Rice Production	References
Vietnam	System of Rice Intensification (SRI) - Alternate Wetting and Drying (AWD) - Early planting - Reduced plant density - Reduced fertilizer application	- Increase rice yield - Increase resistance to unfavorable conditions: Drought, flood, disease - Mitigation of GHG emissions	World Bank, n.d.
	Flood-resistant varieties	- Increase land and crop productivity per unit of water - Increases resistance to heavy rain or flood - Moderate reduction in GHG emissions per unit of food produced	World Bank, n.d.

Table 2 CSA Practice and Impact on Rice Production (Con.)

Country	CSA Practice	Impact on Rice Production	References
	Integrated Crop Residue Management (ICM) - Decomposition of rice straw by using microorganisms - Reduced plant density - Reduced fertilizer application	- Reduction of herbicide use for rice straw - Increase land and crop productivity per unit of water - Increases rice yield by 20%	Vernooy et al., 2018
Malaysia	Use of microorganisms to improve rice straw degradation	- Reduction of 10.14% in GHG in the form of decreasing anaerobic methane during the cultivation season	Rahman et al., 2023
	System of Rice Intensification (SRI)	- Mitigation of GHG emissions by 30-55%	
	Drought-tolerant varieties	- Increases plant growth and yield	
Thailand	Laser Land Levelling (LLL)	- Optimized water use and reduction of waterlogging - Increase rice yields - Mitigation of GHG emissions	Gesellschaft für International Zusammenarbeit (GIZ), 2024
	Alternate Wetting and Drying (AWD)	- Reduction of overuse of fertilizer - Mitigation of GHG emissions	
	Site-Specific Nutrient Management	- Reduction of overuse of fertilizer - Improvement of soil health	
	Rice straw and stubble management by using straw balers	- Mitigation of GHG emissions	
	Drought-tolerant and flood tolerant varieties	- Increase plant growth and yield	Kawasaki, 2024

A similar pattern of CSA practices is found in Vietnam, Malaysia, and Thailand. AWD and climate-tolerant rice varieties are selected and applied in all countries according to the fluctuation of annual rainfall and water scarcity. The climate-tolerant rice varieties are developed and promoted to farmers to increase productivity under extreme climate conditions. Rice Straw management is done in different ways. In Vietnam and Malaysia, microorganisms are used to decompose rice straw in the paddy field, while farmers opt to collect the rice straw using straw balers. In the case of Thailand, the rice would be used for feeding cattle or sold to earn more income. However, farmers may face some difficulty accessing the modern farm machinery and collecting the rice straw from the paddy field. Therefore, the application of microorganisms appears to be a suitable alternative for managing rice straw and stubble. This may be an opportunity for researchers to develop high-potential microorganisms that can rapidly decompose rice straw and stubble.

For Thailand, Deutsche GIZ GmbH established the Thai Rice NAMA project to encourage local smallholder farmers to implement low-emission rice farming. The Half-Half co-payment scheme was introduced to the farmers and agripreneurs in six pilot provinces of Chainat, Singburi, Angthong, Ayutthaya, Pathumthani, and Suphanburi. Laser Land Levelling (LLL), which can optimize water use and reduce waterlogging in the paddy field, was promoted by this Half-Half co-payment campaign (GIZ, 2024). However, the main constraint for LLL application in Thailand was the lack of service providers who can operate the LLL with proper skills. Moreover, there is not enough number of LLL in Thailand for land levelling service. This may be a great challenge for local agripreneurs or local service providers to serve the needs of LLL service.

Challenges and Opportunities for CSA Implementation in Thailand's Rice Production

CSA presents a promising pathway to enhance productivity, resilience, and emissions reduction in Thailand's rice sector. However, its effective implementation requires addressing key challenges across multiple dimensions, involving farmers, policymakers, researchers, and the private sector.

Thailand's rice production is dominated by smallholder farmers with limited access to capital, technology, and agronomic knowledge, which constrains the scalability of CSA practices that rely on collective action or infrastructure development. One significant barrier is the limited availability of timely and site-specific climate and agronomic information, such as weather forecasts and soil data, which constrains farmers' ability to make informed decisions and adopt water and nutrient-efficient practices. Policy misalignment also limits CSA uptake. Although national strategies on climate change exist, support mechanisms like subsidies, credit, and insurance are often inconsistent with CSA goals. Technical constraints, including inadequate irrigation systems and limited access to stress-tolerant rice varieties, further reduce the feasibility of CSA techniques such as AWD. Behavioral resistance, especially among older, risk-averse farmers, remains a significant challenge. The absence of clear short-term benefits or trusted peer models often leads to reluctance in adopting new practices. Addressing these barriers calls for integrated efforts, including targeted extension services and participatory learning, to facilitate behavioral change and promote CSA at scale.

Conversely, several enabling factors support CSA implementation in Thailand. Strong institutional support from entities such as the Department of Rice, Ministry of Agriculture, and Kasetsart University has facilitated the piloting of CSA technologies, including AWD and the System of Rice Intensification. Rising sustainability awareness at both domestic and international levels has increased demand for certified rice such as GAP, organic, and low-carbon rice has created strong market incentives for CSA adoption. Moreover, youth engagement offers strong potential with younger farmers more open to innovation and smart farming technologies that relate to CSA practices.

Conclusions

Climate change presents a multifaceted challenge for global rice production, necessitating adaptive farm practices to ensure food security. Rice producers worldwide, including Thailand, confront rising temperatures, erratic rainfall, and extreme weather phenomena. As in Thailand, the agricultural sector was the second biggest GHG emitter, especially during the flooding period. To mitigate the effects and impacts of climate change, CSA was introduced to farmers in various countries. Similar patterns of CSA practices, such as AWD and the use of climate-tolerant rice varieties, were observed across Vietnam, Malaysia, and Thailand. These shared strategies are instrumental in mitigating water scarcity and enhancing resilience against extreme climatic conditions, thereby directly lessening the effects of climate change on rice production. However, effectively applying CSA requires careful consideration: The optimal CSA practices for rice production in each region must be precisely selected based on its unique local context, encompassing specific climate vulnerabilities, resource availability, and socio-economic factors. Such tailored CSA practices offer alternative farm activities that enable Thai farmers to grow rice with consideration for the sustainability of rice production, thereby increasing competitiveness in the global rice market.

Recommendations

CSA practices are new alternative farm activities that could elevate Thai farmers to promising sustainability. However, there are more practical actions that need to be implemented to achieve CSA practices.

For Government Entities:

• Collaboration with national or international organizations to initiate specific training programs, pilot projects, and demonstrations of CSA practices by training the local government officers and farmers.

• Development of a specific training program for LLL operators and maintenance technicians.

• Providing financial support such as subsidies or low-interest loans for arbitrageurs to invest in agricultural machinery and establish service centers in key rice-producing regions.

For Educational Institution and Industry Experts:

• Offering of upskilling and reskilling programs to implement CSA practices, especially rice production, for local government officers and farmers.

• Fostering collaboration between educational institutions and industry experts to develop low-cost agricultural machinery that is suitable for rice production in Thailand and equip the local knowledge to the local technicians.

For Rice Production Farmers:

• Participation in the training programs, pilot projects and demonstrations to update the necessary knowledge about CSA practices from local government officers or educational institutes.

• Strengthen the accessibility to agricultural machinery by organizing the machinery ring.

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