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Comparative Analysis of Agricultural Institutional Policies on Smallholder Farmers' Food Security: Evidence from Indonesia, China and India

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Abstract | This study analyzes the role of agricultural institutions in enhancing food security and sustainability for smallholder farmers from Indonesia, China, and India, with a focus on the four pillars of food security: availability, access, utilization, and stability. Using a systematic literature review, the study identifies both formal and informal institutional mechanisms that support food security through policies on food diversification, income enhancement, and market access. The review uses the Scopus database, covers publications from 2020 to 2024, and includes 98 articles that meet predefined inclusion criteria for the three countries. Findings show that although agricultural policies contribute to food sustainability, disparities in technology access and funding hinder smallholder farmers, especially in remote areas, from adopting sustainable practices. In addition, policies that support market access, microfinance, and technical training improve food security and economic sustainability at the household level. However, current policies often overlook smallholder farmers in socio economically disadvantaged regions. A lack of institutional coordination and challenges in information access constitute major barriers to policy effectiveness. These insights indicate that more inclusive policies are needed to reduce disparities in access to resources and training, and that further research is required to identify more effective policies for improving food security and agricultural sustainability, particularly in underrepresented areas.

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Introduction

Asia, as the continent with the largest population in the world, is home to over 5.3 × 10^9 people, the majority of whom reside in rural areas and rely heavily on agriculture as their primary source of livelihood (Lam, 2025). These rural farmers are often vulnerable to a range of challenges, such as dependence on limited natural resources, unpredictable weather patterns, and inadequate infrastructure, which

expose them to food insecurity and malnutrition. Currently, over 500 × 10^6 people in Asia face food insecurity, with high levels of malnutrition among children, further exacerbating their quality of life (Li *et al*., 2020). Economic instability and frequent social unrest in various regions of Asia intensify these conditions, creating uncertainties that threaten social and economic stability. This situation often presents significant challenges for smallholder farmers who depend on agricultural outputs for their livelihoods, as fluctuations in food prices and uncertainties in supply can substantially reduce their income (Touch *et al*., 2024). Therefore, food security is critical for maintaining regional economic stability, as the unavailability or unaffordability of food can lead to serious disruptions in both the economy and the well-being of communities (Ejiohuo *et al*., 2024; Savary *et al*., 2020). However, the sustainability challenges within agriculture, such as land degradation, declining water quality, and the impacts of climate change, further worsen the issue of food security in Asia. In this context, a strong and responsive institutional system plays a crucial role in supporting agricultural sustainability and food security by implementing policies that facilitate market access, enhance production capacity, and protect smallholder farmers. Despite this, the institutional systems in many Asian countries still face numerous challenges, including a lack of coordination among agencies, limited effectiveness of policies, and an inability to respond swiftly and appropriately to the needs of farmers. Nevertheless, there is a lack of comparative evidence on how different institutional agricultural policies across Asian countries affect food security outcomes, particularly among smallholder farmers.

Effective institutional systems have great potential to enhance land productivity, improve food availability, and support food security. Policies that facilitate market access, improve financing, and ensure efficient distribution can increase farmers' capacity to produce agricultural outputs sustainably (Giller *et al*., 2021), which in turn boosts food availability. For instance, institutional systems that introduce environmentally friendly agricultural technologies and provide training to farmers can enhance crop yields and reduce losses that occur during production and distribution processes (Osumba *et al*., 2021). However, significant challenges arise when institutional systems are poorly designed. Inadequate policies that do not align with the needs of smallholder farmers, coupled with imbalances between policies and local practices, can hinder land productivity (Asare-Nuamah *et al*., 2021). In some cases, poorly designed institutional systems may exacerbate dependence on unsustainable agricultural techniques, slow down food distribution, and create disparities in access to resources (Figure 1). This can further undermine food security, as food supply becomes unstable and difficult to access for the most vulnerable populations. Therefore, while institutional systems hold significant potential, poor design can negatively impact agricultural productivity and overall food availability (Yuniati *et al*., 2024).

Agricultural institutions play a crucial role in enhancing food security and the sustainability of smallholder farmers through a multi-dimensional approach. These institutions significantly improve food utilization through nutrition-based interventions such as biofortified crops and post-harvest training, as demonstrated by Indonesia's Farmer Field Schools,

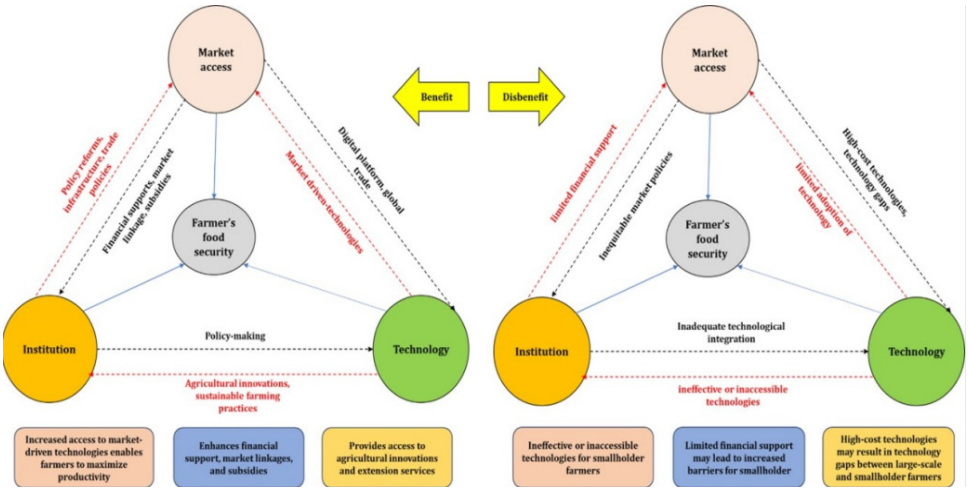

Figure 1: *A generalized framework showing the agriculture institution system and its benefits and disbenefits to farmers' food security.*

which successfully increased crop diversification by 45 % (Mariyono *et al.*, 2021). Simultaneously, these institutions strengthen food stability through climate adaptation programs and price stabilization mechanisms, as exemplified by Nafed India in managing food reserves during crises (Matthan, 2024). However, challenges such as uneven resource distribution and short-term funding models limit their effectiveness, particularly for marginalized groups (McCambly *et al.*, 2023). Policy recommendations highlight the need for an integrated approach that strengthens institutional coordination between the agricultural and social protection sectors, expands digital extension services, and establishes sustainable funding mechanisms, as evidenced by China's success in linking cooperatives with welfare programs.

The role of agricultural institutions in enhancing food security and the sustainability of smallholder farmers has been the subject of extensive research. However, the existing literature still reveals several profound gaps that need to be addressed. Most empirical studies (Aryal *et al.*, 2020; Kogo *et al.*, 2021) tend to focus on the impact of institutions on a single aspect of food security, particularly production and productivity improvements, while overlooking a comprehensive analysis of all food security pillars, including access, utilization, and stability. Existing systematic reviews (Komarek *et al.*, 2020; Raisa *et al.*, 2020; Sheingate, 2000) also primarily concentrate on evaluating formal national-scale institutional programs, with limited attention given to the critical role of informal institutions such as traditional sharecropping systems, rural women's savings and loan groups, or local knowledge-based adaptation mechanisms. Furthermore, the current literature lacks an adequate analytical framework for comparing the effectiveness of various institutional models across Asia's agro-ecological zones, particularly in responding to complex challenges such as changing rainfall patterns, extreme temperature rises, and land degradation (Kostova *et al.*, 2020). As a result, our understanding of how different forms of agricultural institutions can optimally contribute to sustainable food security in the Asian region remains partial and fragmented, necessitating a more holistic and integrated analytical approach to address these gaps.

Agricultural institutions have long been the backbone of food security systems, with various models evolving across different regions. However, findings from existing studies (Lei *et al.*, 2023; Mwadzingeni *et al.*, 2020) are often highly location-specific and have yet to provide a comprehensive comparative understanding of their effectiveness at the regional level. To strengthen the empirical evidence regarding the contribution of agricultural institutions to food security and the sustainability of smallholder farmers, this systematic review is designed to address the following research questions: i) In what geographical and socio-economic contexts have the roles of agricultural institutions in food security in Asia been most documented? ii) How do institutional mechanisms (both formal and informal) contribute to improving food security and the sustainability of smallholder farmers? iii) What challenges and trade-offs arise from institutional interventions in local food systems?

The findings of this study will make an important contribution to policy-making by providing reliable evidence on the effectiveness of various agricultural institutional models in supporting food security for smallholder farmers in Indonesia, China, and India. Additionally, it will guide future research by identifying knowledge gaps that still need to be explored.

Materials and Methods

Literature data collection

In this systematic review, the identification and selection of studies followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses PRISMA protocol (Ekawati *et al.*, 2025; Garfansa *et al.*, 2025). The selection process, including the search and refinement of articles, is summarized in Figure 2, which illustrates the steps taken to identify and select the studies relevant to the objectives of this systematic review. The aim was to explore the impact of agricultural institutions on food security and the sustainability of smallholder farmers in Asia. To ensure a broad and comprehensive collection of relevant studies, Primary databases Scopus was selected. This database was chosen due to robust and reputable search engines, which provide access to high-quality academic literature. The literature search focused on articles published from 2020 to 2024, as this time frame captures both the historical development and the most recent advancements in the field of agricultural institutions in Asia.

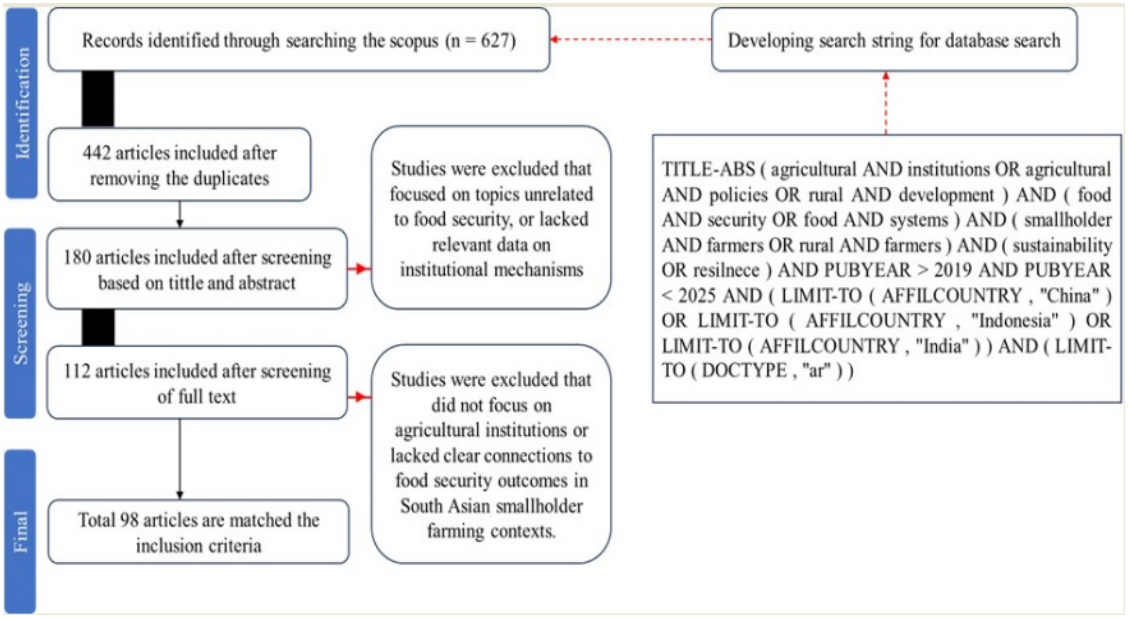

Figure 2: *Summary of the screening and inclusion of publications of the systematic review*

Article screening

In this systematic review, a comprehensive screening of titles and abstracts was carried out to select the most relevant studies examining the role of agricultural institutions in improving food security and sustainability for smallholder farmers in Asia. The screening process adhered to several key inclusion criteria: i) studies that explicitly discuss agricultural institutions or related concepts such as policies, cooperatives, or institutional support mechanisms; ii) studies that explore aspects of food security, including production, access, utilization, or stability of food systems; and iii) studies that focus on smallholder farmers or agricultural practices in Asian countries.

The decision to include only studies from China, India, and Indonesia was based on the significant role these countries play in Asia's agricultural sector. These three nations have large populations of smallholder farmers, significant agricultural economies, and face distinct challenges related to food security and sustainability (Bisht *et al.*, 2020; Zhang *et al.*, 2020). By focusing on these countries, the review aims to provide insights into institutional frameworks and their impact on food security within a region that is crucial to global agricultural sustainability.

From the initial search, 497 articles were retrieved. The publication years were limited to 2020, 2021, 2022, 2023, and 2024 to ensure the inclusion of the most recent research, reflecting the latest advancements and emerging trends in agricultural institutions and food security. Studies published during these years are more likely to address contemporary issues, such as the effects of recent policy changes, institutional reforms, and the impact of global challenges such as climate change on smallholder farmers (Zenda, 2024). Articles published before 2020 were excluded as they may not fully capture the evolving dynamics and current challenges faced by agricultural institutions in these countries.

After screening the titles and abstracts, 180 articles were selected for further review. These articles were thoroughly examined to ensure that they met all the inclusion criteria. Ultimately, 98 studies were included in the final review. Studies that did not meet the criteria were excluded for reasons such as a lack of empirical data, insufficient focus on agricultural institutions, or a focus on unrelated topics like environmental impacts or technological advancements without a clear link to food security and sustainability. Only studies published in English were included to ensure consistency and eliminate potential translation issues.

Data extraction

To address the research questions (RQ), we extracted various types of data from the selected publications. For RQ1, we collected general information including the year of publication, location (country), research focus, and the type of agricultural institutions involved, focusing on the geographical and socio-economic contexts in which agricultural institutions' roles in food security are most documented. For RQ2,

we extracted data on the institutional mechanisms (formal/informal) that contribute to improving food security and sustainability for smallholder farmers, including the roles of cooperatives, government policies, and community support systems. For RQ3, we focused on identifying the challenges and trade-offs arising from institutional interventions, such as dependency, inequality, or environmental impacts, as well as the barriers farmers face in adapting to these interventions. The data was organized and categorized based on institutional contributions to food security and sustainability, as summarized in Table 1 and Table 2.

Results and Discussion

Context and research focus

Among the 98 studies reviewed, publication outputs showed a steady annual increase from 2020 to 2024, with the most dramatic surge occurring between 2023 to 2024 when total publications were 52 % increase (Figure 3). China maintained consistent leadership throughout the period, contributing 45 publications (45.9 % of total). Its annual output grew from 2020 to 2021, dipped slightly to 7 in 2022, then climbed sharply in 2023 and 2024, demonstrating an overall growth rate of 133 % over 5 yr. India followed with 30 publications (30.6 % of total), showing more stable progression. The country's most significant growth occurred in the final year, with a 66.7 % increase from 2023 to 2024. Indonesia accounted for the remaining 23 publications (23.5 % of total). While Indonesia's 2024 output doubled its 2020 baseline, it consistently produced fewer publications annually compared to both China and India.

Table 1: *Description of the research question and type of information recorded for each of the selected publications*

Research question	Category	Description
RQ1. In what geographical and socio-economic contexts are the roles of agricultural institutions in food security in Asia most documented?	Year	Year of publication
	Country	Country where the study was conducted (focused on China, India, and Indonesia)
	Research focus	Focus of the study, including geographical and socio-economic context related to food security and agricultural institutions
RQ2. How do institutional mechanisms (formal/informal) contribute to improving food security and sustainability for smallholder farmers?	Institutional mechanisms	Type of agricultural institutions involved (e.g., formal policies, informal community practices, cooperatives)
	Contribution to food security	How the institutional mechanisms contribute to food security (availability, access, utilization, stability)
	Sustainability aspects	How institutional mechanisms contribute to sustainability, such as income stability, environmental outcomes, and resilience
RQ3. What challenges and trade-offs arise from institutional interventions in local food systems?	Challenges	Identified challenges or negative impacts of institutional interventions (e.g., dependency, policy inefficiency)
	Trade-off	Trade-offs associated with institutional interventions (e.g., short-term food security vs. long-term sustainability)

Table 2: *Contribution of agricultural institutions to farmers' food security*

Pillars of food security	Contribution (Benefits/Disbenefits) of agricultural institutions	
	Dimension (Increasing/Decreasing)	Description
Availability	Food quantity and quality	The role of institutions in improving food production, availability, and diversification of food options through formal or informal mechanisms such as subsidies, technology adoption, and policy interventions.
Access	Market access	Institutions enhancing farmers' access to local, national, or international markets, providing opportunities to sell produce and generate income.
Utilization	Environmental sustainability	The role of agricultural institutions in promoting sustainable farming practices, reducing environmental degradation, and fostering eco-friendly farming practices.
Stability	Resilience to external shocks (e.g., Climate, Market, or Economic)	Institutions help farmers build resilience to environmental shocks (e.g., climate change) or economic disruptions, through safety nets, support mechanisms, or adaptive practices.

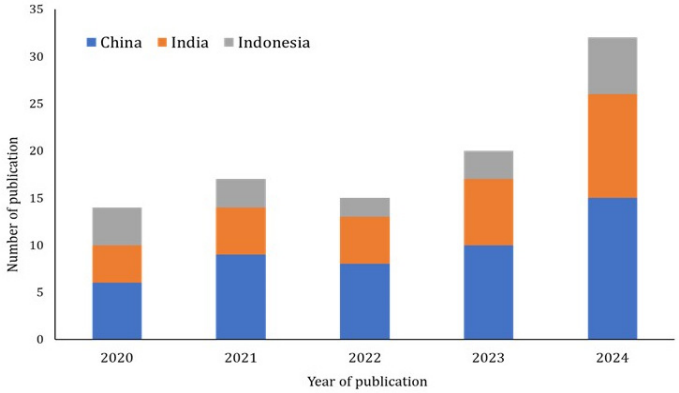

Figure 3: *Numbers of publication based on year of publication*

More than half of the studies analyzed focused on the contribution of institutions to food security, with the majority highlighting the role of government policies in supporting smallholder farmers (Figure 4). The majority of these studies (n = 32) concentrated on market access, followed by financial support (n = 27) and technological innovations in agricultural practices (n = 21). However, not all studies directly addressed food security in its broader sense. Many of these studies also emphasized the role of institutions in developing farmers' capacity, including Sustainable resource management (n = 16) and government policies (n = 2).

Since 2022, there has been an increasing focus on understanding how both formal and informal institutions support smallholder farmers in addressing food security challenges. China has become the country with the highest number of studies on this topic, with a particular focus on financial support (n = 15). This may be attributed to the large size of China's agricultural sector and the heavy dependence of many smallholder farmers on government policies. In India, research has predominantly focused on market access (n = 9), technological innovations in agricultural practices (n = 6), and financial support for smallholder farmers (n = 8). In the case of Indonesia, many studies have concentrated on market access (n = 7) and agricultural technology (n = 6), supported by existing institutional frameworks.

Overall, the primary focus of the existing research is on the role of both formal and informal institutions in supporting food security and the sustainability of smallholder farmers, with varying challenges in each country. Further research is needed to delve deeper into the impact of institutional policies on local food systems, as well as how the interaction between formal policies and informal practices can mutually support the enhancement of food security in Asia.

Benefits and disbenefits of agricultural institutions

Food availability

Of the 98 studies reviewed, 12 studies documented the contribution of agricultural institutions in increasing sustainable resource management for smallholder farmers (Figure 5). For example, a study by (Binh *et al.*, 2022; Tran *et al.*, 2024) found that agricultural institutions in Northern Vietnam promoted sustainable water management practices, which helped increase rice yields by 25 %, yet farmers in remote areas of the region still struggled to access food due to inadequate market infrastructure. Similarly, agroforestry systems supported by local institutions improved soil quality and crop yields by 30 %, but farmers in the southern provinces faced greater challenges in accessing local markets due to poorly developed transportation networks, which limited their ability to sell excess production and

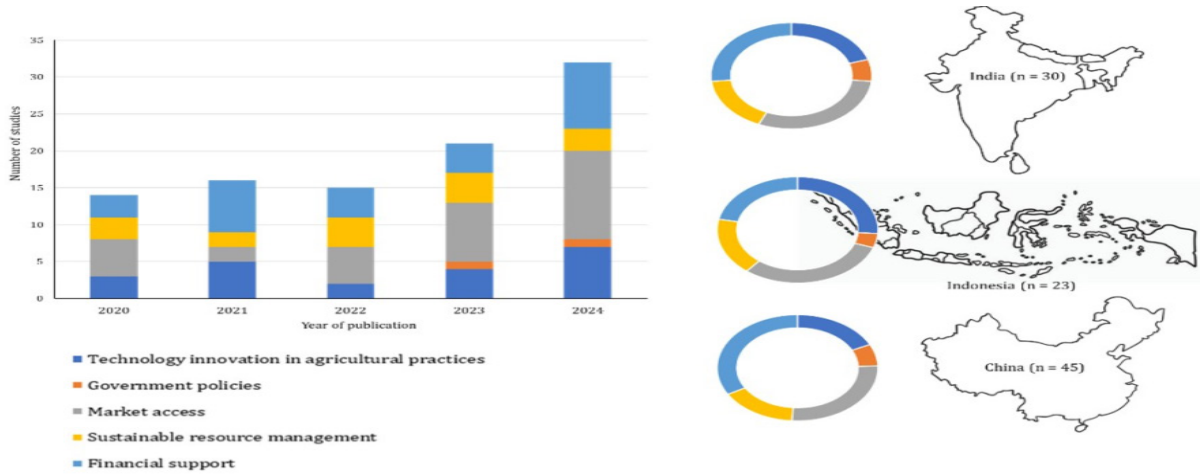

Figure 4: *General information on the studies including research and trends in research focus from 2020 to 2024*

purchase other necessary food items (Park *et al.*, 2022). However, several studies also showed regional disparities in food access. Despite the success of sustainable agricultural practices in increasing food production, these efforts are often undermined by barriers to market access, particularly in remote areas. Research by Ma *et al.* (2024) confirmed that although improved water management practices led to more efficient resource use and higher yields, poor infrastructure and limited access to markets in rural areas continued to hinder smallholder farmers' ability to sell their produce and access diverse food supplies. Moreover, Jinger *et al.* (2023) in Laos found that while agroforestry practices improved soil health and crop production, disparities in access to technology and poor market infrastructure exacerbated food access issues in remote regions, underscoring the need for integrated policies that address both sustainable farming practices and equitable market access (Ohiwal *et al.*, 2025).

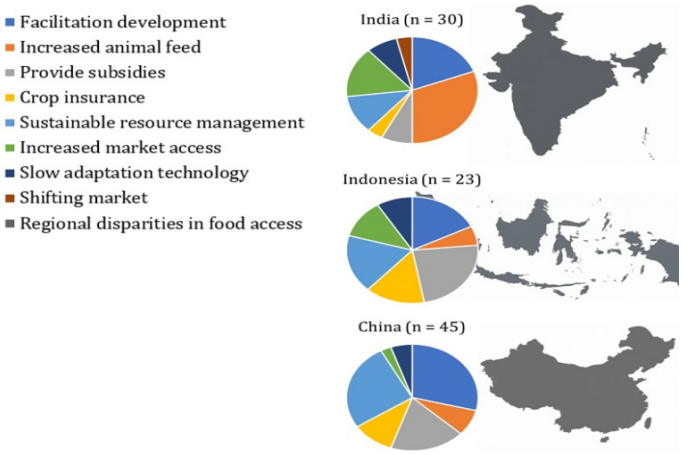

Figure 5: *Benefits and disbenefits of institution agricultural to Asian farmers' food (a) availability, (b) access, (c) utilization, and (d) stability.*

In terms of food production, 22 studies reported improvements in infrastructure facilities driven by institutions, contributing to food security through enhanced storage facilities, better irrigation systems, and more efficient market access. These infrastructure improvements enabled smallholder farmers to reduce post-harvest losses and ensure a more stable food distribution at both the household and market levels. The enhancement of irrigation systems plays a critical role in increasing food availability, particularly in areas facing water scarcity or climate disruptions. Studies by Liu *et al.* (2022) and Shah *et al.* (2023) reported that the use of precision irrigation technology in China significantly improved water use efficiency and agricultural yields. Furthermore, improved storage facilities provided by agricultural institutions help reduce post-harvest losses, which are often caused by inadequate storage capacity. This is particularly important given the large quantities of agricultural products that are lost before reaching the market. For example, in India, Mohan *et al.* (2023) noted that the improvement of post-harvest storage facilities, facilitated by government programs, successfully reduced agricultural waste by 15 %, giving farmers more opportunities to sell their products at better prices. Meanwhile, Gertler *et al.* (2024) demonstrated that improved rural road infrastructure enabled more efficient distribution and enhanced market access.

Additionally, more than 10 studies highlighted the role of agricultural institutions in improving livestock feed availability to support the food security of smallholder farmers. In India, agricultural institutions play a vital role in facilitating livestock feed provision by offering feed subsidies, developing feed storage infrastructure, and providing training for farmers to manage feed efficiently. For example, the National Dairy Development Board (NDDB) has implemented programs to improve smallholder farmers' access to quality livestock feed, including providing feed storage facilities and increasing the production of forage crops in rural areas to ensure year-round feed availability (Chaturvedi *et al.*, 2024). Moreover, policies supporting the development of drought-resistant feed varieties and environmentally friendly feed technologies have been introduced to reduce dependency on expensive and imported feeds (Kona *et al.*, 2025). These programs may helped farmers cope with climate change and weather fluctuations, which frequently affect livestock feed availability.

Food access

Although the income generated from institutional-supported agricultural practices varies depending on land size and the components involved, the majority of studies (n = 20) indicate that agricultural institutions significantly contribute to the income of smallholder farmers in Asia, primarily through improved market access. This contribution comes from direct income increases compared to traditional agricultural practices, as well as indirect benefits gained through reduced labor requirements (Wang *et al.*, 2023) and the creation of employment opportunities for family members (Leng, 2022). Additionally, the sale of agricultural products supported by institutions

helps farmers reduce the need to borrow money from family or neighbors, highlighting the crucial role of institutions in stabilizing their income (Karyani *et al*., 2024).

Several studies also show that enhanced market access through government policies and agricultural cooperatives allows smallholder farmers to sell their products in local, national, or international markets, thereby increasing their income. For instance, in India, institutionalized agricultural practices enabled farmers to achieve better prices through market linkages facilitated by government policies focused on increasing access to foreign markets (Tripuraneni and Robbins, 2024). Other research indicates that integrating agriculture with livestock and non-agricultural products helps farmers diversify their income sources, strengthening their position in broader markets (Higgins *et al*., 2023). However, despite the improved market access facilitated by agricultural institutions, challenges remain regarding the empowerment of local markets, which are still limited. Some studies suggest that greater access to international or national markets does not always correspond to long-term sustainability in price stability. In countries like Indonesia, farmers sometimes face sharp price fluctuations and uncertainty due to inconsistent market policies, which exacerbate their market access, despite institutional efforts to improve it (Baur *et al*., 2024).

Food utilization

Overall, many studies highlight the positive contribution of agricultural institutions in introducing sustainable farming practices that reduce environmental degradation and enhance agricultural ecosystem sustainability. Twelve studies have reported that sustainable natural resource management through institutional interventions, such as organic fertilizer subsidy programs and the introduction of environmentally friendly farming techniques, plays a crucial role in reducing reliance on chemicals harmful to soil and water. In countries like Indonesia, government policies supporting the use of organic fertilizers and manure in agriculture have been shown to reduce dependence on synthetic fertilizers (Fahmid *et al*., 2022), which often lead to soil degradation and water pollution. These sustainable farming practices not only improve soil quality but also help maintain ecological balance (Prasetyo *et al*., 2022a; Saijo, 2024). For example, several government policies in India and China that support the use of natural pesticides and crop rotation management have helped reduce the negative impacts of harmful chemicals that can pollute groundwater and decrease biodiversity (Dyah *et al*., 2022; Reddy *et al*., 2024; Xie *et al*., 2023). Research in Indonesia has demonstrated that agroforestry practices, driven by local policies, have improved soil quality by reducing erosion and enhancing the soil's capacity to retain water, which is critical for long-term food security (Sujianto *et al*., 2022).

Additionally, institutional policies supporting soil conservation and rainwater management in agricultural areas have also contributed to environmental sustainability. In Indonesia, the implementation of efficient irrigation techniques and soil conservation programs promoted by local governments has increased agricultural productivity while protecting natural resources (Sumaryanto *et al*., 2022). These programs enable farmers to reduce excessive water use and optimize natural resource utilization more efficiently, supporting food production sustainability without compromising the environment. However, despite the many documented benefits, challenges remain, such as limited access to environmentally friendly technologies in remote areas and long-term reliance on policies that have not fully reached smallholder farmers. For example, despite policies supporting the use of organic fertilizers, some farmers are still hindered by resource limitations and lack of market access for environmentally friendly products (Prasetyo, *et al*., 2022b; Sukorini *et al*., 2023).

Food stability

Institutional policies also play a crucial role in enhancing food security through the provision of subsidies (n = 13) and crop insurance (n = 8), which provide financial protection to smallholder farmers in the face of challenges related to natural disasters and market uncertainty. In China, crop insurance programs have provided vital protection for farmers against losses caused by extreme weather events such as storms, floods, or droughts. These programs help farmers maintain their income even in the event of crop failure due to unpredictable weather conditions. For instance, China's Crop Insurance Program, introduced in 2016, aims to offer financial protection to farmers, and it has proven effective in mitigating the negative impacts of climate change on food production (Li *et al*., 2022). This program not only compensates for direct losses caused by adverse weather but also

helps stabilize farmers' income by offering affordable premium payments and government-subsidized insurance. This enables farmers to maintain economic stability despite the increasing unpredictability of weather. In recent years, crop insurance in China has expanded to cover more crop types, including key commodities such as rice, wheat, and maize, which are essential for national food security.

In Indonesia, institutional policies that provide subsidies for agricultural inputs, such as fertilizers and quality seeds, serve to reduce production costs for smallholder farmers, thereby improving their market access and food availability. The fertilizer subsidy program launched by the government, allows farmers to reduce dependence on fluctuating market prices and improve their food security (Purnamasari *et al*., 2023). Research by Jamil *et al*. (2023) also demonstrates that these subsidies play a crucial role in reducing rural poverty and enhancing agricultural productivity sustainably. Hendrawan *et al*. (2024) further add that subsidies for agricultural technology contribute to the adoption of more efficient farming practices, which ultimately increases food production and supports agricultural sustainability in Indonesia.

The need for comprehensive assessment of agricultural institutions' impact on food security

Although various studies have examined the role of agricultural institutions in supporting food security, there remains a significant gap in assessing the impact of these institutions on food security as a whole. The analysis reveals that many studies focus more on specific elements of food security, such as agricultural yield, income, or food diversification, without considering how changes in one aspect can affect others. For instance, while some studies assess the impact of agricultural institutions' policies on crop yields or smallholder income, very few have analyzed how improvements in these areas affect food stability, accessibility, or the quality of food utilization at the household level.

The findings also indicate that while agricultural institutions support sustainable natural resource management, such as through efficient irrigation programs or the use of environmentally friendly agricultural technologies, not all smallholder farmers experience these positive impacts equally. A key finding from this research is the regional disparity in food access. For example, although the implementation of sustainable agricultural systems in certain regions has significantly increased crop yields, areas with underdeveloped market infrastructure continue to face challenges in distributing their agricultural products to broader markets (Losch, 2022; Ma *et al*., 2024), which, in turn, hinders stable and affordable food access. This suggests that more holistic policies need to be implemented to not only improve productivity but also enhance market access and food distribution effectively.

Moreover, existing studies indicate that while agricultural institutions contribute to increasing food production capacity, many policies do not sufficiently consider the long-term relationship between agricultural practices and environmental sustainability. For example, some policies that encourage the use of intensive agricultural technologies often risk degrading soil quality or causing water pollution, which can be detrimental in the long run, even though they may result in short-term yield increases (Chaudhuri *et al*., 2023; Francaviglia *et al*., 2023). Therefore, there is an urgent need for more in-depth research on the negative impacts of agricultural institutions' policies, particularly those related to human health and the environment.

Institutional mechanisms and smallholder farmers' economic sustainability: balancing short-term losses and long-term gains

In many of the studies reviewed, both formal (e.g., government policies, subsidies, and funding programs) and informal (e.g., farmer cooperatives, local social networks) institutional mechanisms play a crucial role in enhancing the economic sustainability of smallholder farmers. However, the implementation of these policies often presents trade-offs between short-term losses faced by farmers and the long-term benefits they may gain. These policies may result in a reduction in short-term income but offer the potential for greater financial gains in the future, through improved food production sustainability and the diversification of products produced by smallholder farmers.

For example, many institutional policies that promote sustainable agricultural practices often require significant initial investments, which may lead to a decrease in farmers' income in the short term. This is particularly evident when smallholder farmers must transition to environmentally friendly technologies

or diversified farming practices, which take time to implement and show results. Policies encouraging the use of organic fertilizers or crop rotation may reduce farmers' reliance on chemical fertilizers in the long run (Zhang *et al*., 2022a). However, on the other hand, farmers may experience temporary yield declines when shifting from more conventional farming techniques.

Based on findings indicating sustained income generated from long-term institutional policies, such as agricultural subsidy programs and market access, long-term benefits often outweigh temporary losses. In India, for instance, policies supporting the use of drought-resistant crop varieties and efficient irrigation technologies have shown that, despite high initial costs, the long-term sustainability of agricultural yields is much more stable and can mitigate economic losses caused by weather fluctuations (Pandey *et al*., 2024; Prasad *et al*., 2024). In China, agricultural subsidy policies that support crop diversification have helped smallholder farmers achieve more stable incomes by reducing their dependence on a single seasonal crop vulnerable to market price fluctuations or unpredictable climate conditions (Fan *et al*., 2023; Zhang *et al*., 2022b).

However, a key challenge faced by smallholder farmers is the difficulty in accessing such institutional support, both in the form of initial funding and access to technical training needed to maximize the benefits of these policies. Smallholder farmers are often limited in their access to credit or market information, which hinders their ability to invest in long-term, sustainable agricultural practices. For example, although many policies offer subsidies for efficient irrigation or the planting of new crop varieties, access to initial capital is often a significant barrier for farmers who lack access to formal financial institutions or cooperative networks.

Therefore, it is essential for institutional policies to strengthen support systems that can alleviate the financial burden on farmers adopting new policies. For instance, policies providing direct subsidies, technical training, and better access to agricultural resources can reduce the barriers faced by smallholder farmers in balancing short-term losses and long-term gains (Bai *et al*., 2024). Agricultural cooperatives and local farmer groups can play a crucial role as intermediaries, offering improved market access, funding, and training to farmers facing difficulties. Thus, more holistic institutional mechanisms that consider the challenges smallholder farmers face in accessing economic resources and funding can help create smoother pathways for them to achieve long-term benefits from sustainable agricultural policies, while minimizing the temporary losses they experience.

The trade-offs between agricultural modernization and environmental sustainability

One of the biggest challenges in implementing agricultural institutional mechanisms is finding a balance between agricultural modernization and environmental sustainability. On one hand, agricultural modernization offers the potential to increase productivity and farmer incomes through the use of new technologies and intensive farming principles. On the other hand, the use of more intensive farming practices often has negative environmental impacts, such as soil degradation, biodiversity loss, and water pollution due to the use of chemicals like pesticides and synthetic fertilizers (Das *et al*., 2022). Therefore, it is essential to discuss how agricultural institutions can guide policies that support agricultural modernization while ensuring environmental sustainability.

For example, in countries like China and India, government policies promoting agricultural modernization often focus on increasing agricultural output through the adoption of advanced technologies, such as chemical fertilizers and technology-based irrigation systems. However, the use of environmentally unfriendly technologies often leads to soil fertility decline and environmental damage, which can undermine long-term agricultural sustainability. A study conducted in Indonesia shows that although agricultural modernization successfully increased rice yields in the short term, excessive use of pesticides and chemical fertilizers resulted in soil quality deterioration and water pollution (Fahmid *et al*., 2022).

There are more sustainable institutional approaches that can be implemented to achieve environmentally friendly agricultural modernization. One such approach is product diversification, which encourages farmers to rely not only on a single main commodity but to integrate various types of crops and livestock into a more holistic farming system. For example, policies supporting agro-ecosystem-based farming

that combines food crops, trees, and livestock not only increase farmers' incomes but also improve soil quality, enhance biodiversity, and stabilize the climate (Çakmakçı *et al*., 2023).

However, there are significant challenges in ensuring that institutional policies supporting these sustainable farming practices are implemented equitably across the country, especially for smallholder farmers who lack access to adequate technology or financial resources. Green agriculture subsidy programs and funding for green technologies are often limited to large-scale farmers who have access to markets and financial resources. Therefore, to ensure that environmentally friendly agricultural modernization is accessible to all farmers, agricultural institutions must provide stronger support programs for smallholder farmers, offering greater access to environmentally friendly technologies and market access that supports sustainable agricultural products.

Developing more holistic and integrated policies that combine agricultural modernization and environmental sustainability is crucial to ensuring that farmers can benefit in the long term without compromising the environment that supports their food production. Agricultural institutions should play a key role in introducing efficient farming practices, green technologies, and product diversification, while ensuring that access to technology and financial resources is available for smallholder farmers who continue to face limitations in adapting to technological changes.

Addressing the socio-economic gaps in agricultural policies for smallholder farmers

Despite the various agricultural institutional policies implemented in Asia to improve food security and agricultural sustainability, many smallholder farmers, especially those in remote areas, are often neglected in the implementation of these policies. One of the main challenges faced by smallholder farmers is the disparity in access to essential agricultural resources, training, and technologies needed to improve their productivity and sustainability. This disparity is often exacerbated by infrastructure limitations, geographical isolation, and a lack of access to markets and financing.

According to the literature reviewed, many of the policies implemented in larger countries like India, China, and Indonesia focus more on large-scale farmers or those in economically advanced regions. This results in smallholder farmers in remote areas struggling to access the institutional support they need. For example, although various subsidy programs, training initiatives, and technological access are available, most smallholder farmers lack sufficient information about these programs, l *et al*one receive adequate financial support to implement new, more environmentally friendly, and sustainable technologies. To address this disparity, agricultural policies need to be more inclusive and context-based.

Cross country similarities and differences in institutional policies

Agricultural institutions in Indonesia, China, and India exhibit several consistent policy patterns that support food security among smallholder farmers. All three countries maintain input subsidy programs that include improved seeds, fertilizers, soil conservation resources, and technical support that aim to strengthen food availability. Each country has developed instruments to expand market access and enhance smallholder income through value chain integration, improved marketing infrastructure, and strengthened local institutional capacity. There is also a common effort to promote the adoption of agricultural technologies through training programs, digital advisory services, and increased mechanization that aim to improve production efficiency and resource utilization. In addition, all countries have implemented risk mitigation instruments such as crop insurance schemes and compensation programs that aim to maintain income stability in the face of climate disturbances and price volatility.

Despite these shared features, the three countries demonstrate notable differences in policy orientation and institutional implementation. China places strong emphasis on climate adaptive technologies, varietal innovation, and modernization of water management systems that result in improved production stability and enhanced adaptive capacity. India places greater focus on price and market related policies through minimum purchase price arrangements, domestic market interventions, and expanded export opportunities that prioritize improved food access and income generation. Indonesia places priority on subsidy programs and community-based capacity enhancement with attention to improved land management practices and support for smallholder

farmers. However, implementation is affected by geographical disparities due to limitations in infrastructure and extension services in remote areas. These variations in institutional orientation create differences in their respective contributions to the four pillars of food security, especially in income stability and environmental sustainability.

Conclusions and Recommendations

This study has revealed various pathways of contribution, demonstrating how agricultural institutions play a crucial role in contributing to the four pillars of food security in Asia, particularly for smallholder farmers. Both formal and informal institutional mechanisms are vital in ensuring food availability by enhancing the diversity of food products and providing a more varied range of nutritional resources. The increased and diversified income derived from agricultural products supports the pillar of food access, enabling farmers to access more nutritious food. Additionally, institutional policies that emphasize sustainable agricultural practices contribute to more stable food security, both in food production and in maintaining a more sustainable diversity of agricultural products.

This study also highlights the environmental benefits that arise from the implementation of institutional policies supporting agricultural sustainability in Asia. These environmental benefits include improved soil fertility, erosion control, water conservation, and reduced carbon emissions, all of which are crucial for ensuring long-term food security. However, it is important to note that a lack of proper species selection and poor management practices in some regions has led to decreased agricultural yields, crop income losses, and biodiversity loss, which can threaten the food security of smallholder farmers. Therefore, it is critical to strengthen agricultural extension services across Asia, which can provide technical guidance and support to farmers interested in adopting sustainable farming practices. These extension services should include training, demonstrations, and consultancy assistance, focusing on proper species selection, crop mixture techniques, and sustainable management practices.

While this study highlights the significant contributions of agricultural institutions to food production, farmer incomes, health, and environmental services, there are limitations that hinder the drawing of definitive conclusions regarding the extent to which institutional mechanisms can ensure food security for smallholder farmers in Asia. These limitations arise from the lack of concrete quantitative data and the research focus still being concentrated on specific regions, particularly India, China, and Indonesia. Furthermore, most existing studies primarily highlight the advantages and disadvantages of agricultural institutional mechanisms without considering the role of livestock, which also contributes to the agro-forestry-livestock farming system. To gain a more comprehensive understanding of how agricultural institutional mechanisms contribute to food security in Asia, it is essential to integrate more quantitative assessments that cover a wider range of geographical conditions and include all components of the agro-forestry-livestock farming system.

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Novelty Statement

Previous research (Aryal *et al.*, 2020; Komarek *et al.*, 2020; Raisa *et al.*, 2020) has examined the role of agricultural institutions in supporting food security, mostly by focusing on single aspects such as productivity or formal policy interventions. However, these studies often overlook the comprehensive interaction between all four pillars of food security (availability, access, utilization, and stability), especially in relation to both formal and informal institutions. The current systematic review offers a new perspective by conducting a cross-country comparative analysis between Indonesia, China, and India, three major agricultural economies in Asia. This research uniquely integrates formal and informal institutional mechanisms and identifies key trade-offs between short-term and long-term impacts of agricultural policies. Furthermore, it highlights regional disparities and socio-economic gaps in policy implementation, offering a holistic framework for enhancing the economic and environmental sustainability of smallholder farmers in Asia.

Authors Contribution

Pardin Lasaksi: Writing – original draft, conceptualization.
Sutawi Sutawi: Methodology, data curation.
Bambang Yudi Ariadi: Conceptualization, supervision.
Wa Ode Al Zarliani: Writing – review & editing, supervision.
Marchel Putra Garfansa: Methodology, conceptualization, writing – review & editing.
Waris Ali Khan: manuscript review
All authors have read and approved the final manuscript

Generative AI and AI-assisted technology statement
The authors state that they used generative AI and AI-assisted technology in preparing this manuscript, specifically utilizing ChatGPT to enhance English grammar and manuscript clarity. The Authors remain fully responsible for the content of this manuscript.

Conflict of interest
The authors have declared no conflict of interest

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