Agronomy for Sustainable Development (2024) 44:27
https://doi.org/10.1007/s13593-024-00960-w

REVIEW ARTICLE

Factors influencing the adoption of sustainable agricultural practices for rice cultivation in Southeast Asia: a review

Sheng-Han-Erin Chang[1] · Emmanuel O. Benjamin[2] · Johannes Sauer[1]

Accepted: 18 March 2024 / Published online: 23 April 2024

Abstract
Rice cultivation plays a vital role in the Southeast Asian (SEA) economy, but it poses environmental challenges and contributes a significant amount of greenhouse gas emissions. To address these concerns, sustainable agricultural practices (SAPs) for rice production have been introduced to mitigate the environmental impact of rice production while fostering economic and social sustainability. However, the adoption of these practices remains limited, highlighting the need for a critical review of existing literature to gain deeper insights into the factors influencing farmers' adoption of these practices in SEA countries. This review analyzed 39 manuscripts to assess the current state of SAPs for rice cultivation in SEA. We found that socio-demographic variables and farm management variables were frequently examined in these studies, with varying levels of significance. Economic and institutional variables were moderately studied and tended to have more significant findings. There is a noticeable research gap regarding behavioral factors, emphasizing the need for further investigation in SEA. Furthermore, the findings underscore the importance of conducting additional research to develop effective monetary and non-monetary incentives and explore methodologies to address the gaps in understanding farmers' trade-offs and preferences among different SAPs. These efforts are crucial for promoting the widespread adoption of SAPs in rice cultivation.

Keywords Sustainable agricultural practices · Adoption · Rice cultivation · Systematic review · Southeast Asia

1 Introduction

Rice cultivation has historically played an important role in the economic and social development of many Southeast Asian countries (SEA). SEA comprises "mainland" (Cambodia, Laos PDR, Myanmar, Thailand, and Vietnam) and Island regions (Malaysia, Indonesia, and the Philippines) that collectively contribute 26% to global rice production and 40% to exports (Yuan et al. 2022). Mainland and island regions are characterized by tropical and subtropical climatic zones with high annual precipitation.

The majority of rice producers in these countries are smallholders with four main types of rice cultivation systems as follows: irrigated, rainfed, deep water, and upland rice (usually on sloping land) (Mutert and Fairhurst 2002). Irrigated rice systems exhibit the highest productivity, followed by rainfed, deep water, and upland rice. In Indonesia, Malaysia, the Philippines, and Vietnam, irrigation systems are more prevalent. Conversely, Cambodia, Laos, Myanmar, and Thailand primarily rely more on rain-fed lowland cultivation (Mutert and Fairhurst 2002). Despite these differences, all these countries face common challenges—balancing the increasing demand for rice with sustainable agricultural practices and addressing the impact of climate change.

According to the IPCC (2007), in the agricultural sector, global paddy rice cultivation contributes approximately 30% and 11% of global methane (CH4) and nitrous oxide (N2O) emissions, respectively. In Southeast Asia, rice cultivation is a major contributor to GHG emissions in the agricultural sector, with an average of 20% of total GHG emissions at the country level, as indicated by national GHG inventory data (Zhang et al. 2024). For instance, in Thailand in 2019, rice cultivation contributed 54.7% of total GHG emissions (Mungkung et al. 2022). Open-field burning of rice straw after harvest releases carbon dioxide (CO2) at 70%, CH4,

✉ Sheng-Han-Erin Chang
sheng-han-erin.chang@tum.de

1 Agricultural Production and Resource Economics, Technical University of Munich, Alte Akademie 14, 85354 Freising, Germany

2 Department of Development Economics and Policy, University of the Bundeswehr Munich, Werner-Heisenberg-Weg 39, 85579 Neubiberg, Germany

carbon monoxide (CO) at 7%, and N2O at 2.09% (Singh et al. 2024). This burning process also leads to the depletion of soil organic matter content (Connor et al. 2020). It is estimated that global rice production must increase by 30% by 2050 in order to satisfy the projected rice demand for the growing world population (Yuan et al. 2022). However, growing more rice will eventually result in increased GHG emissions.

In this region, rice can be grown up to three times per year with the use of irrigation (Mutert and Fairhurst 2002). The production of rice poses great challenges with its usage of 34 to 43% of global irrigation water (Surendran et al. 2021). In Asia, irrigation consumes over 80% of freshwater resources, and more than half of that is used for rice irrigation (Surendran et al. 2021). This intensive water usage significantly contributes to area-based water scarcity (Silalertruksa et al. 2017; Mungkung et al. 2019). To address this challenge, the water footprint has been introduced. It serves as a tool to assess the link between agricultural production, water resources, and environmental impacts, with the aim of improving water use efficiency, sustainability, and management (Silalertruksa et al. 2017; Rusli et al. 2018). Over-application of agro-chemical inputs is another major constraint for sustainable rice production in Asia (Terano et al. 2015; Devkota et al. 2019; Flor et al. 2020; Nguyen et al. 2022). In certain countries (Indonesia, Malaysia, the Philippines, Vietnam, and Thailand), rice production is characterized by high levels of agrochemical inputs to achieve self-sufficiency and support exports in rice production (Cho and Zoebisch 2003; Olabisi et al. 2015; Ali et al. 2018; Digal and Placencia 2018; Atieno et al. 2020; Fritz et al. 2021). This has resulted in adverse health effects and has had negative environmental impacts (Sapbamrer 2018).

Rice fields are not just for agricultural productivity but also providers of various ecosystem services. They contribute to cultural (recreation, cultural identity, tourism), regulating (biocontrol, pollination), and provisioning services (soil nutrients) in Southeast Asia (Settele et al 2018). In light of these valuable contributions, it becomes evident that climate change poses a significant threat to these ecosystem services, particularly in SEA, which is recognized as one of the most vulnerable regions to climate change. Those unsustainable farming practices mentioned above lead to environmental degradation and make it even more difficult to mitigate and adapt to climate change. In response to these challenges, sustainable agricultural practices (SAPs) have emerged within rice cultivation systems. These practices mainly include climate-smart agriculture, conservation agriculture, integrated pest management, nutrient management, organic farming, and straw management. SAPs have been shown to be effective in reducing agro-chemical application and the amount of water used, and in increasing crop yield (Seerasarn et al. 2020; Ha and Bac 2021). SAPs in rice cultivation have the potential to achieve several Sustainable Development Goals (SDGs) including zero hunger (SDG 2), clean water and sanitation (SDG 6), responsible consumption and production (SDG 12), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15). Therefore, there is a need to increase farmers' uptake of SAPs in Asia and to improve societal benefits.

To date, no comprehensive review has systematically summarized sustainable rice farming practices and identified determinants of adoption in this region. Thus, this study aims to address this gap by providing a critical review that not only examines the methods used in previous studies but also synthesizes their findings, ultimately identifying key research gaps. The objectives of this study are threefold. Firstly, it aims to identify and summarize the most common SAPs for rice cultivation that have been implemented in SEA countries, including a detailed analysis of their sustainability levels, as discussed in Section 3.1. Secondly, it aims to analyze and evaluate the existing literature on the determinants of adoption, including the factors that influence farmers' decision-making. Lastly, it aims to highlight the methodological approaches used in previous studies and assess their strengths and limitations.

2 Materials and methods

Most systematic review studies on motivation and the factors determining the participation of AES or adoption of SAPs were conducted mainly on a regional or global scale. For example, Serebrennikov et al. (2020) conducted a systematic review and identified factors influencing the adoption of SAPs in Europe. They found that farmers' environmental and economic attitudes and their sources of information have a strong impact on their adoption of organic farming. Sapbamrer and Thammachai. (2021) conducted a global systematic review of factors influencing farmers' adoption of organic farming. They found that extension agents, farm associations, and the government are three key drivers for this adoption. Guo et al. (2020) conducted a comprehensive review of the literature on the adoption of sustainable intensification (SI) in Southern African farming systems. They identified nine relevant drivers of the adoption of SI among smallholder farmers including age, education, extension services, gender, household size, income, farming organization membership, size of arable land, and access to credit. Begho et al. (2022) reviewed factors influencing farmers' adoption of sustainable crop farming practices in South Asia. They discovered that factors such as education, training and extension programs, soil quality, irrigation, income, and access to credit play a significant role in influencing farmers' decision-making. A systematic review conducted by Jones et al. (2020) highlighted the importance of both financial and non-financial motivations in influencing participation in payment for ecosystem services (PES) programs in the global south. Foguesatto et al. (2020) reviewed the literature on factors influencing the adoption of SAPs worldwide. Their study suggests that farmers' perceptions are influenced by economic and psychological factors. They discovered the majority of papers they reviewed ignored the inclusion of psychological factors involving farmers' adoption decisions. Furthermore, the constructs (i.e., farmers' perception) were poorly measured in those reviewed papers concerning psychological factors.

This review primarily focuses on the voluntary adoption of sustainable practices, regardless of whether they are supported by the government or NGOs. This study is based on identifying factors that motivate or hinder farmers' independent decision-making about SAPs, rather than evaluating the impact of external interventions. We concentrated on factors found to be statistically significant in predicting SAP adoption. As this study includes research on using multiple methods such as various regression models or structural equation modeling, a comparison of the effect sizes of these influential factors is beyond the scope of this study. In our study, SAPs include approaches that not only enable rice farmers to implement environmentally friendly practices but also contribute to their economic stability and social well-being. These practices include, but are not limited to, methods such as organic farming, the system of rice intensification (SRI), integrated farming (rice with livestock or fish), good agricultural practices (GAP), integrated pest management (IPM), and rice straw management (RSM). Besides giving an overview of common SAPs for rice production, our review focuses on empirical findings on factors driving or limiting the adoption of SAPs in rice production in SEA. These practices are viable for smallholders, allowing them to make the best use of their resources and land.

2.1 Inclusion criteria

While a number of studies on the technical experiment or economic performance of SAPs in rice cultivation exist, they were omitted in this study. This study included articles that (1) analyzed the adoption of sustainable rice cultivation practices such as reducing greenhouse gas emissions from rice production, decreasing irrigation water use, reducing agro-chemical use, and implementing sustainable straw management; (2) applied statistical methods and used primary data for empirical research in SEA countries; (3) published in peer-reviewed journals and proceedings; (4) published between 1993 and 2022; and (5) published in English. In terms of farmer adoption, the vote-counting method was employed to synthesize evidence from multiple studies in order to categorize the findings into three categories: (1) studies reporting positively significant results; (2) studies reporting negatively significant results; (3) studies reporting non-significant results. This method identified whether a specific variable in a factor exhibits a consistent pattern or mixed results across studies (Priya and Singh 2022). However, we recognize the inherent diversity and context-specific nature of studies conducted in SEA, which can affect their comparability. Therefore, we interpret these categorized results with caution. When a variable shows significantly positive results in the majority of the studies, it is considered to have a positive effect on SAP adoption.

2.2 Search methods

We searched relevant articles in several databases including Web of Science, Scopus, and Google Scholar by using the following keywords: "adoption" OR "determinants" OR "factor" plus "attitude" OR "preference" OR "perception" plus "organic rice farming" OR "system of rice intensification" OR "sustainable agriculture practices" OR "integrated pest management" OR "climate-smart" OR "integrated farming" OR "Good agriculture practices" OR "Best management practices" OR "green manure" plus "Cambodia" OR "Indonesia" OR "Laos" OR "Malaysia" OR "Myanmar" OR "Philippines" OR "Thailand" OR "Vietnam" OR "Southeast Asia".

2.3 Quality assessment

Our systematic review follows the PRISMA guidelines (Moher et al. 2009). The flow diagram in Fig. 1 depicts the study selection procedures. A total of 1341 records were initially identified from Web of Science, Scopus, and Google Scholar. After removing duplicates, 429 articles underwent abstract screening. Out of these, 298 studies were excluded for not being conducted in SEA countries or focusing on unrelated practices. Further, full-text examination led to the exclusion of 33 additional articles due to inappropriate study design or a lack of focus on adoption and rice cultivation. Ultimately, 39 articles met the inclusion criteria for the review.

2.4 Data analysis

The data were presented based on author, year of publication, country, study population, and findings and recommendations. Several studies have identified and categorized the factors influencing the farmers' decisions to adopt SAPs. Tu et al. (2018) classified the factors affecting adoption of eco-friendly rice production into eight subgroups: (1) sociodemographic characteristics (age, education, experience, gender, and labor); (2) perception of risk; (3) perceived usefulness (benefit, selling price, yield); (4) perceptions about environment pollution and biodiversity; (5) perceived ease

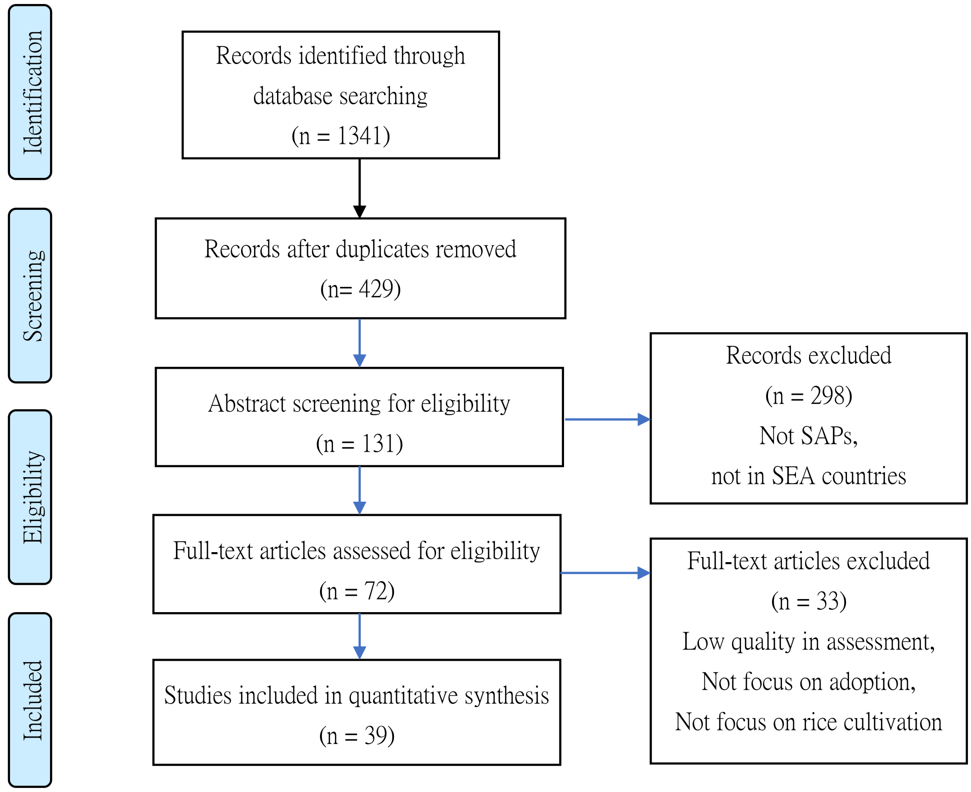

Fig. 1 Diagram outlining steps and results of article screening, adapted from the PRISMA protocol (Moher et al. 2009).

of use (technical aspect); (6) farm physical characteristics (farm size and plots); (7) social network (membership in organizations), and (8) financial characteristics (perception of outside support and access to credit). Pham et al. (2021) categorized factors into four groups: (1) plot characteristics (size, ownership, distance, plot problem, quality, land slops); (2) household characteristics (age, education, gender); (3) resource constraints (assets, food expenditure, labor, livestock units index, off-farm income, total cultivated plots); and (4) social capital (political connections, relatives, membership of farmer groups, sharing with peers, contact with extension agents). Priya and Singh (2022) grouped variables affecting general SAPs adoption into 6 categories: (1) social-economic factors (e.g., age, gender, farm income, etc.), (2) biophysical factors (e.g., farm size, location, distance to market, etc.); (3) institutional factors (e.g., training, input subsidies, policy support, etc.); (4) financial factors (e.g., debt/assets, access to credit, crop insurance, etc.); (5) technological factors (access to knowledge, technical assistance, asset owned, etc.); and (6) psychological factors (e.g., intention to adopt, perception, attitude, etc.). According to recent studies (Dessart et al. 2019), behavioral/psychological factors play a significant role in the adoption of SAPs. They grouped them into three clusters from more distal to more proximal: (i) dispositional factors; (ii) social factors; and (iii) cognitive factors. Based on the above-mentioned studies, this study identifies a comprehensive set of six groups for factors affecting SAP adoptions, including (1) socio-demographic characteristics; (2) farm characteristics and farming factors; (3) economic factors; (4) institutional factors; (5) social factors; and (6) behavioral/psychological factors.

In our systematic review, the studies analyzed had significant heterogeneity in methods and measures applied, including the use of structural equation modeling, which did not report the mean and standard deviation data required for traditional effect size calculations. Consequently, we employed a vote-counting method to synthesize the findings and to discern common themes and issues. While vote-counting has limitations, which will be detailed in Section 3.4, and may not capture the full complexity of the studies, it can still provide a useful summary of the findings and offer insights for future research.

3 Results and discussion

This section presents and discusses the results of the systematic review. In terms of the geographical location, seven countries in SEA have relevant publications: Cambodia (1), Indonesia (6), Malaysia (4), Myanmar (1), Philippines (2), Thailand (12), and Vietnam (13) (Table 1). However, no relevant papers were found for Laos. A detailed summary with findings and recommendations of each study is shown in Table A1 in the Appendix. Section 3.1 outlines the most

Table 1 Counting of studies on rice SAPs adoption in SEA countries. *KH* Cambodia, *ID* Indonesia, *MM* Myanmar, *MY* Malaysia, *PH* Philippines, *TH* Thailand, *VN* Viet Nam, *AWD* alternate wetting and drying, *BMP/GAP* best management practices/good agricultural practices *CSA* climate-smart agriculture, *EF* eco-friendly, *GFT* green fertilizer technology, *HPRS* Hill pond rice system, *IF* integrated farming, *IRL* integrated rice and livestock farming, *IRF* integrated rice and fish, *Mixed SAPs* mixed sustainable agricultural practices, *OF* organic farming, *RSM* rice straw management, *SRI* system of rice intensification, *SLM* sustainable land management, *1M5R* one must do-five reduction.

SAPs/country	KH	ID	MM	MY	PH	TH	VN	Total
AWD					1			1
BMP/GAP			1	1		2		4
CSA							3	3
EF		1					1	2
GFT				1				1
HPRS						1		1
IF						1		1
IRL		3						3
IRF		1					1	2
Mixed SAPs				1			1	2
OF		1			1	5	2	9
RSM						2	1	3
SRI	1			1			1	3
SLM						1	1	2
1M5R							2	2
Total	1	6	1	4	2	12	13	39

Table 2 Sustainability levels of agricultural practices in rice cultivation.

SAPs	Environmental sustainability	Economic sustainability	Social sustainability
Organic farming	High: reduced agro-chemical use, improved soil health, biodiversity preservation	Moderate to high: potential for premium pricing but with higher initial costs	High: safe working conditions, healthier food options
Climate Smart Agriculture (incl. SRI and AWD)	High: efficient water usage, lower GHG emissions	High: increased yield, reduced water costs	High: improved resilience to climate change, food security
Integrated farming (incl. Rice-Fish, Rice-Livestock)	High: efficient resource use, enhanced ecological balance	High: income diversification, risk mitigation	High: enhanced food security, diversified diets
Good agricultural practices / Best management practices	Low: aim to minimize environmental impact	Moderate to high: potential to improve efficiency and product quality	Moderate: safer working conditions
Rice straw management	High: reduces air pollution, enhances soil health	Moderate: cost-saving in waste disposal, adds value when straw is used effectively	Moderate: pollution reduction, provides additional resources for communities

common SAPs implemented in SEA. Section 3.2 presents the factors most frequently examined that affect the adoption. Section 3.3 identifies research gaps, summarizes analysis methods, and discusses limitations.

3.1 Rice SAPs adoption in SEA

As shown in Table 1, organic farming adoption was the most studied ($n = 9$), followed by Climate Smart Agriculture including SRI and AWD ($n = 7$), integrated farming, integrated rice-fish farming, integrated rice-livestock farming ($n = 6$), Good Agricultural Practices/Best Management Practices ($n = 4$), and rice straw management ($n = 3$). These findings may indirectly indicate the region's policy priorities. Table 2 presents the sustainability levels of these SAPs and the following section will provide a detailed analysis of each practice.

3.1.1 Organic rice farming (OF)

During the 2000s, organic agriculture gained prominence in Southeast Asian countries thanks to the support of international NGOs and development agencies (Castella and Kibler 2015). Adoption of organic agriculture practices can be effective in improving farmers' livelihood and conserving agro-biodiversity (Limnirankul and Gypmantasiri 2012). By reducing agro-chemical inputs, promoting crop rotation, and vegetative buffer zones, organic agriculture has the potential to regenerate agricultural land, prevent soil degradation, and counteract biodiversity loss (Fritz et al. 2021). According to Neang et al. (2017), in Cambodia, around 85% of farmers are rice producers. Cambodian organic rice farmers have lower social status because OFs are perceived as old-fashioned and only used by "poor" farmers (Neang et al. 2017). There is not enough of a price premium for organic rice to encourage farmers to adopt this practice (Neang et al. 2017). In Indonesia, organic agriculture remains a very small proportion of total agricultural land (0.2 %) despite almost 30 years of civil society initiatives and government efforts to promote OF (Fritz et al. 2021). Sujianto et al. (2022) investigated Indonesian rice farmers' perception, motivations, and constraints in the adoption of OF and the level of awareness as well as their belief in OF in the future. They conclude that organic rice farmers and conventional farmers have different perceptions of production, quality, health and safety, price and market, environmental concerns, and certification. In Malaysia, the Malaysian Agricultural Research and Development Institute is actively supporting organic farming (Somasundram et al. 2016). Although the government launched the "Go Organic" program in 2001, the program was not successful, since the adoption rate of OF has remained low (less than 0.1 percent) (Ashari et al. 2018). In Thailand, the organic rice sector accounts for 30.4% of total organic products (Kerdsriserm et al. 2016). The Thai government has promoted OF through various strategies including "a crop diversification program," "financial incentives," and "training programs." However, the adoption of OF has been slow (Seerasarn et al. 2020). In Vietnam, rice farming remains economically viable, so the transition to a more environmentally friendly farming method has been relatively slow (van Aalst et al. 2023).

3.1.2 Climate-smart agriculture (CSA)

CSA is sustainable agriculture incorporating resilience concerns, while at the same time, seeking to reduce greenhouse gas emissions (Ha and Bac 2021). Climate-smart agriculture is a way to combine various sustainable methods to address climate challenges faced by specific farming communities. This involves the adoption of high-yield and drought-tolerant varieties, changing schedules for planting dates, and adopting the system of rice intensification (SRI), minimal tillage, and intercropping (Ha and Bac 2021; Duc Truong et al. 2022).

System of rice intensification (SRI) SRI is the most well-known CSA including a set of rice cultivation practices which produce higher yields and increase water-use efficiency while being environmentally friendly. SRI is particularly effective in increasing rice productivity while reducing production costs, hence enhancing farmer profitability (Ly et al. 2012; Zaman et al. 2017). In rice-producing countries, SRI has been introduced and has been adopted by many farmers in Cambodia, Indonesia, Malaysia, Thailand, and Vietnam (Doi and Mizoguchi 2013; Aris and Fatah 2019; Ha and Bac 2021; Arsil et al. 2022; Ly et al. 2012). SRI includes a low-cost water-saving technique called Alternative Wetting and Drying (AWD) allowing rice farmers to switch from continuous flooding of paddy fields to intermittent flooding, which has the potential to minimize methane emissions (Samoy-Pascual et al. 2021). Mao et al. (2008) conducted a qualitative analysis of SRI adoption in Cambodia and found that the rice yield increased when farmers changed to SRI implementation. Linquist et al. (2015) estimated that AWD can lower the global warming potential of rice production by 45–90%. Several factors influenced the decision to adopt AWD, not only socioeconomic factors, but also the institutional arrangements within the irrigation association, and the biophysical conditions relative to the distance to water sources (Samoy-Pascual et al. 2021). Nguyen and Hung (2022) investigated the adoption of SRI and its impact on rice yield in the upland region of central Vietnam. They found that age negatively affects SRI adoption, while family labor, number of plots, and access to credit positively affect adoption. SRI adoption was found to increase rice yield by 15.1%, and their results suggest a need for coordinated policies to support SRI implantation in mountainous areas, particularly in training farmers to use the technique. Furthermore, Mao et al. (2008) found that low soil fertility, labor shortage, lack of irrigation systems, drainage and water sources, insufficient organic fertilizer, little knowledge of diseases and pest control, and moreover, natural disasters are challenges farmers have to face and may hinder them from practicing SRI.

3.1.3 Integrated farming (IF)

IF is based on the integration of crops and livestock into production systems and maintains a high level of soil fertility and productivity. Moreover, IF seeks to replace external inputs of energy, agrochemicals, and labor with on-farm resources and natural biological cycles and processes (Purnomo et al. 2021). Integrated rice-livestock (IRL) farming involves several resource-saving practices and efficient farming methods that minimize the negative effects of intensive farming and preserve the environment while achieving acceptable profits and sustained levels of production (Widadie and Agustono 2015). Small-scale farmers will need additional technology and management to enhance their self-sufficiency and resource-use efficiency by integrating crop and livestock systems (Widadie and Agustono

2015). The integrated rice–duck farming (IRDF) is also included in this category because it integrates ducks feeding on insects and weeds in paddy rice fields, while at the same time, duck manure is a good fertilizer to nourish the soil. It has served as a model for the Asian sustainable agriculture movement (Suh, 2014). Bunbongkarn (2013) found the factors influencing the adoption of IF are different among farmers in lowland and upland areas. For example, three factors were significantly associated with the adoption in lowland areas, namely participation frequency of integrated farming training programs, income from vegetables, and percentage use of natural fertilizers. For upland areas, the factors are the number of years of experience in practicing IF, the amount of loans for IF, and water adequacy.

Integrated rice–fish (IRF) farming is a more sustainable alternative to rice monoculture, which could reduce pesticide use, increase nutrient recycling, and improve ecological sustainability, while also supporting economic sustainability (Berg 2002). IRF may increase farm income and improve farm productivity (Bosma et al. 2012). Moreover, IRF and IPM are complementary activities and rice–fish farmers should be an important target group for the development and application of the IPM program in the region (Berg 2002).

3.1.4 Good agricultural practices (GAPs) and best management practices (BMPs)

GAPs and BMPs allow sustainable farms to use agro-chemical inputs in moderation, as long as it does not jeopardize their overall sustainability. A report by Premier and Ledger (2006) highlights the Southeast Asian governments' efforts to address a uniform standard through the development of the Association of Southeast Asian Nations (ASEAN) scheme for Good Agricultural Practice (GAP), a standard applicable to all ASEAN member countries. GAP is the benchmark for a food safety-based plan aiming to satisfy export requirements. This program is designed to certify that GAP-labeled rice is produced according to best practices for (1) farm-level hygienic conditions, (2) management of agricultural equipment and tools, (3) management of inputs, (4) control of production and practices, and (5) control of accounting and documents (Srisopaporn et al. 2015).

In Indonesia, Connor et al. (2021) found that rice farmers can produce rice more sustainably, and their livelihood can be positively improved by national and regional governments' projects to promote BMPs. In Malaysia, GAP was launched in 2013 to promote sustainable agriculture practices. A study by Terano et al. (2015) found that Malaysian paddy farmers are willing to practice sustainable agriculture based on GAPs. Since 2012, the Thailand Rice Department (TRD) has been advocating for a comprehensive set of BMPs known as the Cost-Reduction Operating Principles (CROP) aiming to increase farmers' income by cutting down costs while preserving or increasing yields through the "Three Must Do" and "Three Must Reduce"[1] recommendations. (Stuart et al. 2018). Similar to Thailand's BMPs, in Vietnam, the "One Must Do, Five Reductions" (1M5R)[2] program, designed to promote BMPs in lowland rice cultivation, was certified as a national approach by the Ministry of Agriculture and Rural Development in 2013 (Tho et al. 2021).

We found that Integrated Pest Management (IPM) adoption for rice cultivation was usually investigated together with GAPs/BMPs. For example, Terano et al. (2015) examined farmers' adoption of GAP including IPM, and Dung et al. (2018) studied the factors affecting the adoption of 1M5R and IPM. Integrated Pest Management (IPM) is a crop protection strategy which has the potential to minimize pesticide application while increasing productivity. Pesticide spray reduction could not only benefit the environment but also reduce workdays used for spraying which could lower input costs and thereby result in higher income for farmers. Josue-Canacan (2022) investigated the constraints and motivation in IPM adoption in the Philippines. She found that increasing farm productivity and income were key motivations for farmers to attend training programs whereas lack of time and capital were major constraints. In Indonesia, although IPM was implemented in rice cultivation, Bulkis et al. (2020) found there has actually been an increase in pesticide use among rice farmers in many parts of the country. This has been linked to increasing brown planthopper attacks in various rice-producing areas in Java. Compared to the low IPM adopters, the high IPM adopters earn higher profits (Bulkis et al. 2020).

According to GAP/BMP standards, farmers are allowed to use agro-chemicals but only at certain times of crop growth. Therefore, farmers only need to fulfill basic farming practice requirements that are not always beneficial to the environment and do not mitigate climate change. However, they can still serve as a starting point for promoting SAPs with proper implementation and monitoring. GAPs/BMPs could gradually shift farmers toward more sustainable practices, such as reducing the use of agro-chemicals. As such, they can be viewed as a stepping stone toward a more sustainable and climate-resilient agriculture.

[1] Three must do: (1) limiting crop planting to two times per year; (2) using high-quality seeds, and (3) recording farming production costs and income. Three must reduce: (1) seed rate applications, (2) incorrect fertilizer application practices; (3) unnecessary chemical applications.

[2] One must: farmers must use certified seeds; five reductions: (1) seed rate, (2) nitrogen fertilizer, (3) pesticide, (4) water, and (5) post-harvest loss

3.1.5 Rice straw management (RSM)

Increasing the rice production will also increase a high amount of additional rice straw residues. A common practice in SEA is burning the straw directly in the field. Farmers favor this method of managing crop residues as it offers several benefits. It helps counteract the immobilization of nitrogen induced by the residues, improves control over diseases and insect infestations, eliminates weed seeds and seedlings, and assists in eradicating rodents (Kaur et al. 2022). However, open-field rice straw burning has not only a negative impact on human health but also emits significant amounts of carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N2O) (Romasanta et al. 2016), which increase GHG emissions and air pollution (Connor et al. 2020). In addition to destroying soil organic matter, burning also reduces beneficial soil bacteria (Mandal et al. 2004). Farmers may rationalize rice straw burning, despite the fact that they realize this could lead to high risks for human health and the environment. For example, farmers may think burning is the only option if the fields are difficult to access (Connor et al. 2020).

Keck and Hung (2019) examined in Vietnam two practices: (1) rice residue burning or (2) incorporating rice residue into the soil, and evaluated the associated costs and benefits. Their analysis revealed that while burning residues may have negative ecological consequences, it remains economically rational for farmers. Consequently, they contend that persuading farmers to shift away from this prevalent practice would require financial compensation to cover additional expenses. Connor et al. (2020) investigated several options for rice straw management (Connor et al. 2020), namely rice straw incorporation, rice straw burning, rice straw composting, rice straw compacting, biogas production from rice straw, urea-treated rice straw, and rice straw collection (self-propelled baler, roller baler, loose straw collection). Each of these practices has its own advantages and disadvantages, depending on how well farmers handle the practices. For example, the incomplete decomposition of rice straw produces methane emissions (Wassmann et al. 2000).

3.2 Factors influencing the adoption of SAPs

This review identified a total of 138 variables, including eight socio-demographic characteristics, 53 farm management factors, 18 economic factors, 12 institutional factors, one social factor, and 45 behavioral factors. A detailed list of variables can be found in Table A2 of the Appendix. We only include variables that appear in at least two or more studies in this manuscript because variables that are rarely found in the literature provide less information for policy reference. However, we should include those variables with statistical significance, even if they only appear once in the analysis because such variables as behavioral/psychological factors are emerging in recent studies and require further research (Priya and Singh 2022). Table 3 thus summarizes the 74 key factors out of a total of 137 variables that influence adoption.

3.2.1 Socio-demographic factors

The age of farmers has been used as an essential explanatory variable in most SAP adoption studies, they indicate that young farmers are more likely to adopt new practices (Priya and Singh 2022). In this review, the effect of farmers' age was examined in 21 papers. Only six studies thereof found this factor to be negatively significantly correlated with adoption, namely concerning younger farmers. Whereas two studies found elderly farmers are more likely to adopt SAP. Moreover, 13 thereof have no statistical significance. Global literature indicates a positive correlation between education level and SAP adoption (Priya and Singh 2022). The association between education level and adoption was assessed in 26 papers. As demonstrated in Table 3, there was a more frequent positive correlation between adoption and education level, meaning that farmers with a higher level of education are more likely to adopt SAPs. For example, education was identified as a crucial predictor for BMP adoption in Myanmar (Wehmeyer et al. 2022). However, there are 10 papers indicating that this factor was not statistically significant. Farming experience was assessed in 16 papers. Half of them report positive statistical significance. Moreover, the effect of gender on adoption was examined in 13 studies, two thereof show positive whereas five thereof show negative effects on adoption. There are 11 studies assessing correlations between the household variable and adoption. Only one shows negative, and three thereof show positive statistical significance, whereas seven thereof did not show any statistical significance.

3.2.2 Farm characteristics and farming factors

It is generally assumed that farmers with larger farm sizes may be more likely to invest in technology improvements (Dung et al. 2018; Song et al. 2020). However, in this review, mixed results have been found as described: there are 25 studies examining the correlation between farm size and adoption, with results differing across studies; eight studies found a positive statistical significance, and 13 thereof had no significance. In many developing countries, land ownership is positively correlated with SAP adoption (Priya and Singh 2022). Land ownership was assessed in ten studies, four of which found this factor to be positively significantly correlated with adoption, and two thereof show a negative effect. The association between the number of farm laborers

Table 3 Factors have statistically significance on the adoption of SAPs. *Sig (+)* positive significance, *Sig (−)* negative significance, *N-Sig*: non-significant; (−) the variable is always not significant; *the variable is always negatively significant; **has a mixed significance; ***the variable is always positively significant.

Socio-demographic characteristics factors (6)	Sig(+)	Sig(−)	N−Sig	Total	
Age	2	6	13	21	**
Education level	15	1	10	26	**
Farming experience	8	1	7	16	**
Gender	2	5	6	13	**
Household size	3	1	7	11	**
SAP farming experience	1	0	1	2	**
Farm management factors (13)					
Distance to the sales market for the products	1	2	0	3	**
Distance to buy the inputs	1	1	0	2	**
Family labor	1	0	3	4	**
Farm size/plot size	8	4	13	25	***
Having livestock on farm	2	1	0	3	**
Land ownership	4	2	4	10	**
Number of plots	3	0	2	5	**
Number of labors	2	1	7	10	**
Number of livestock	2	0	1	3	**
Pest and disease	1	1	0	2	**
Rainfall index	1	1	0	2	**
Soil fertility	1	1	0	2	**
Water availability	1	0	1	2	**
Economic factors (6)					
Amount of loans	1	0	1	2	**
Access to credit	5	1	4	10	**
Farm income per year	5	0	0	5	***
Income only from rice	0	1	1	2	**
Off-farm income per year	2	1	4	7	**
Yield per hectare	1	1	1	3	**
Institutional factors (9)					
Access to extension	6	0	2	8	**
Access to information (including climate change)	4	1	1	6	**
Access to irrigation	1	0	2	3	**
Frequency of visits of extension workers	2	0	1	3	**
Frequency of contact with traders	1	0	1	2	**
Membership of cooperative	5	0	5	10	**
Membership of farmer's association	1	0	5	6	**
Participation in SAP training	6	1	2	9	**
Participation frequency in integrated farming training	3	0	0	3	***
Behavioral/psychological factors (40)					
Attitude toward to risk	1	0	1	2	**
Awareness of SAP/GAP/IPM/AWD	2	1	0	3	**
Attitude toward the SAP benefits	2	0	1	3	**
Attitude toward integrated organic crop-livestock farming	1	0	0	1	***
Attitude toward organic farming	2	0	0	2	***
Attitude toward green fertilizer technology	1	0	0	1	***
Attitude toward insufficient labor	1	1	0	2	**
Attitude toward lack of knowledge on straw compost	0	2	0	2	*
Attitude toward sufficient support from government	2	0	1	3	**
Attitude toward difficulty in making straw compost	0	1	0	1	*

Table 3 (continued)

Socio-demographic characteristics factors (6)	Sig(+)	Sig(−)	N−Sig	Total	
Attitude toward problem of conventional farming	1	0	0	1	***
Comparative usefulness of behavior	1	0	0	1	***
Complexity of the SAPs	1	1	0	2	**
Environmental concerns	2	0	0	2	***
Expected cost reduction	1	0	0	1	***
Group norm	2	0	0	2	***
Knowledge about climate change	2	0	0	2	***
Knowledge about SAP/GAP/IPM/integrated	7	0	0	7	***
Mass Media	1	0	0	1	***
Moral obligation	1	0	1	2	**
Observability	1	0	0	1	***
Perceived pro-environmental personal norms	0	1	0	1	*
Perceived cues to rice straw utilization	0	1	0	1	*
Perceived ease of use	1	0	0	1	***
Perceived behavior control	3	1	1	5	**
Perceived severity of rice straw burning	0	1	0	1	*
Perceived ascription of responsibility	0	1	0	1	*
Perceived benefits of rice straw utilization	0	1	0	1	*
Perceived benefits of current option	1	0	0	1	***
Perceived selling price of output	1	0	0	1	***
Perceived cost	1	0	0	1	***
Perceived awareness	1	0	0	1	***
Perception toward biodiversity	1	0	0	1	***
Perception toward water management as a good weed control method	1	0	0	1	***
Perception of integrated farming	1	0	0	1	***
Risk perceptions	3	1	0	4	**
Risk aversion	0	1	0	1	*
Subjective norm	2	0	1	3	**
Trialability	1	0	0	1	***
Understanding the benefit of SAP	1	0	0	1	***

and adoption was examined in ten papers. However, seven of which show no statistical significance.

3.2.3 Economic factors

A total of 18 economic factors have been identified (Table A2 in Appendix). Most of the economic variables have appeared only once in our review. As mentioned in Section 3.2, those factors that appeared less than twice have been removed, since there is limited evidence for concluding that any of those economic factors can be a major driver of SAP adoption. Thus, only six economic variables remain in Table 3. Having access to credit is often reported as one of the major challenges in SAP adoption (Priya and Singh 2022). In this review, access to credit was assessed by ten studies, five of which showed significant positive effects, and only one revealed a significant negative effect on SAP adoption. Seven studies have investigated the effect of off-farm income on adoption. Only two studies show positive and one negative statistical significance. The association between farm income (per year) and adoption was investigated in five studies. The result shows this had a significantly positive effect on adoption. The higher the farm income, the more likely farmers will adopt the SAPs. Many studies recommended that governments provide incentives to farmers for the conversion to SAPs (Digal and Placencia 2018; Tu et al. 2018; Yanakittkul and Aungvaravong 2020).

3.2.4 Institutional factors

The influence of institutional factors, including membership of cooperatives, farmers' associations, and seed growers' associations, has been examined. Among these, only 6 studies reported a statistically significant positive effect on adoption, while the remaining studies found no statistical significance. Access to extension services and information has consistently been identified as an important factor in fostering adoption (Dung et al. 2018; Tran et al. 2019). Our results are in line with previous studies that access to extension impacted positively on adoption. Nine studies investigated the effect of participation in SAP training, with six of them demonstrating a positive statistical significance on adoption. Additionally, participation frequency in integrated farming training was examined by three studies, and the results show that this factor has a positive effect on adoption. Moreover, government support also emerges as a significant factor in integrated rice farming (Purnomos et al. 2021).

3.2.5 Social factors

Tran-Nam and Tiet (2022) suggested that social factors such as peer influences, and social and personal norms are critical components for the adoption of organic farming. In our review, there is only one study that examined one of the social factors, namely whether neighbors practicing SAPs influence the adoption. However, that study found there was no statistical significance; hence, it is not listed in Table 3.

3.2.6 Behavioral/psychological factors

Out of 39 studies reviewed, seven investigated the influence of behavioral/psychological factors on SAP adoption. Although 45 variables were identified as behavioral/psychological factors, the evidence of these influencing factors on SAP adoption is very limited due to only seven papers paying attention to behavioral factors. We include behavioral/psychological variables with statistical significance, even if they appeared only once in the analysis because they are emerging in recent studies and require further research. Knowledge about SAPs was analyzed in seven studies, and knowledge about climate change was analyzed in two studies. Farmers' attitudes, perceptions of SAPs, and farmers' knowledge were found to have a positive statistical significance on adoption. Farmers who perceive the benefits of SAPs and have a positive attitude toward them are more likely to adopt SAPs. However, Myanmar farmers perceive GAPs as difficult to apply despite their benefits (Oo and Usami 2020). Support expectations from the government and institutions have impacts on rice straw management practices (Connor et al. 2020). Among the behavioral factors, farmers' attitudes toward SAPs were found to be a significant predictor of adoption. The review also found that perceived behavioral control, pro-environmental motivations, risk perception, and subjective norm were important factors for SAP adoption, which is consistent with the findings by Adnan et al. (2017), Dessart et al. (2019), and Jones et al. (2020). Understanding the underlying factors that influence farmers' decision-making and their attitudes toward SAPs is crucial for promoting sustained adoption of these practices. Therefore, more research on investigating the correlation between behavioral/psychological factors and SAP adoption needs to be encouraged.

3.3 Identification of research gaps, analysis, and limitations

There are several research gaps that warrant attention in future studies. First, while the existing literature primarily focused on the adoption of specific sustainable practices, further research is needed to investigate the synergies and trade-offs among different SAPs across all three dimensions of sustainability: environmental, economic, and social. This includes exploring how these practices interact and contribute to the overall sustainability level in rice cultivation. Second, there is a need for more research on the social factors that influence adoption such as social norms and networks, and which social factors interact with other factors such as economic and institutional factors to influence adoption. Third, despite the growing importance of behavioral/psychological factors in adoption studies globally, very few relevant studies have been conducted in Southeast Asian countries, and hence, there remains a significant gap in the literature. Fourth, most studies were conducted in a single country, while there is a need for comparative studies across different countries in Southeast Asia. Such studies can provide insights into the factors promoting or hindering the adoption of specifically targeted SAPs in different contexts.

In our review, we observed that a majority of the studies employed regression analysis ($n = 33$), with the most common subtype being specified as logit, probit, or multiple linear regression, cox model ($n = 1$), and tobit regression ($n = 1$). The remaining articles ($n = 4$) used structural equation modeling. Additionally, we examined whether the conceptual models used in the studies were derived from established behavioral models. Only five studies explicitly mentioned the application of theoretical behavioral models such as the Diffusion of Innovation (DOI), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), Health Belief Model (HBM), and Value-Belief-Norm (VBN). Some studies categorized farmers into different groups, such as adopter group and non-adopter groups ($n = 12$), as well as subgroups based on levels of adoption, including overall adoption, partial adoption, discontinued adoption, and continued rejection ($n = 1$) (Table A1 in Appendix). These classifications allowed for a more nuanced understanding of the adoption patterns among farmers.

It is important to acknowledge the limitations of this systematic review. First, the search was limited to articles published in English, which may have excluded relevant literature published in other languages. Second, while efforts were made to ensure the quality of the studies included, it is possible that some bias or error may have been introduced due to limitations in the study design or implementation of the reviewed papers. Furthermore, it is crucial to address the limitations of the vote-counting method: (1) it can oversimplify the data, potentially leading to a loss of detailed information from individual studies; (2) there is a risk of interpretative bias, as aggregating results may not accurately represent the varied contexts and methodologies of the studies; and (3) it does not account for the magnitude of effects, which is critical in understanding the impact of the studied factors. Despite these limitations in the vote-counting method, it can still provide a foundation for more in-depth analyses and future research directions.

4 Conclusion and recommendations

This systematic review focuses on investigating the increasing empirical studies about SAPs implemented in rice cultivation and factors influencing farmers' adoption in SEA countries. We found that the adoption of organic farming is the most studied topic in SEA countries, followed by GAPs/BMPs and CSA/SRI. The results suggest that SAPs can be effective in achieving food security, improving rice productivity, reducing agro-chemical inputs, mitigating the impact of climate change, decreasing water consumption for irrigation, and promoting farmer livelihoods. However, the evidence in this review demonstrates that the adoption rate of those SAPs is low in the SEA region.

The factors influencing farmers' adoption of SAPs in SEA countries exhibit a complex interplay of similarities and differences. To enhance the adoption of SAPs for rice cultivation in SEA, it is essential to learn from the experiences of SEA countries. Organic farming and climate-smart agriculture have been extensively studied in the region, and the government should continue to promote them. Evidence shows that subsidizing organic inputs could increase the likelihood of adoption in Indonesia, the Philippines, and Vietnam. Increasing awareness of farmers and enhancing the extension systems is emphasized in Malaysia, Thailand, and Vietnam. Based on this systematic review, the following recommendations are made to enhance the adoption of SAPs for rice cultivation in Southeast Asia.

4.1 Knowledge exchange and collaborative research

It is important to establish knowledge exchange platforms and collaborative research initiatives that facilitate cross-border sharing of experiences, expertise, and research findings among farmers, researchers, and policymakers across SEA. There is a need to increase awareness and education among farmers and policy makers. In some cases, countries in SEA may prioritize economic development over environmental conservation, leading to a lack of investment in agri-environmental programs. Furthermore, farmers' knowledge about climate change and sustainable agricultural practices is an important factor that can influence their decision to adopt SAPs and their ability to implement these practices effectively. Therefore, there is an urgent need to enhance farmers' knowledge through multifaced approaches such as increasing extension services and establishing field schools and information campaigns for farmers. Encouraging farmers' participation in SAP training and raising the frequency of participation could increase the SAP adoption rate.

Although the adoption of sustainable agricultural practices such as organic farming has been gaining popularity, there is still a lack of understanding on how behavioral/psychological factors influence farmers' decision-making in Southeast Asian countries, particularly in relation to rice cultivation. In order to promote the adoption of SAPs and ensure the long-term sustainability of rice cultivation, it is important to understand the trade-offs that farmers face when considering these practices. Future research should focus on identifying the factors that influence farmers' trade-offs between different agricultural practices in rice cultivation. One potential area of investigation is how both psychological factors and the effects of governmental policies and support programs such as economic incentives and non-monetary incentives influence farmers' decision-making. To address the existing gap of neglecting the exploration of synergies and trade-offs among different SAPs, it is imperative for future research to investigate the interrelationships and potential conflicts between various SAPs in the context of rice cultivation.

4.2 Develop supportive policies

Governments in SEA should develop relevant policies that incentivize the adoption of SAPs by designing comprehensive agri-environmental programs. These programs often require significant resources to implement, and therefore, it is essential to have supportive policies to encourage farmers' engagement. Governments can provide financial incentives to farmers who adopt SAPs. Although regulations and financial incentives may encourage initial adoption decisions, they may not be sufficient to support long-term changes in farmers' practices (Defrancesco et al. 2018), especially in Southeast Asian countries where budget limitations may be a challenge. Furthermore, subsidies for any SAPs have been argued as being unsustainable, and farmers may switch back to conventional farming if financial support for SAPs were to be discontinued (Mills et al. 2017; Dessart et al. 2019).

Public policies can play a crucial role in improving farmers' access to credit as it is an essential factor for the success of farmers and their agricultural businesses. Incentives can be particularly effective when they are designed to address the specific needs and constraints of farmers. For example, in areas where access to credit is limited, providing loans at low-interest rates can help farmers invest in new equipment and inputs necessary for SAP adoption. Our review suggests that policy interventions should focus on enhancing institutional support and economic incentives and on improving access to credit, information, and training.

Appendix

Table 4 Summary of studies on the adoption of the SAPs for rice cultivation. *AWD*, alternate wetting and drying, *BMP/GAP* best management practices/good agricultural practices, *CSA* climate-smart agriculture, *EF* eco-friendly, *GFT* green fertilizer technology, *HPRS* Hill pond rice system, *IRL* integrated rice and livestock farming, *IRF* integrated rice and fish, *IF* integrated farming, *Mixed SAPs* SAP-mixed sustainable agricultural practices, *OF* organic farming, *RSM* rice straw management, *SRI* system of rice intensification, *SLM* Sustainable Land Management, *1M5R* one must do-five reduction.

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Cambodia ($n = 1$)						
Lee and Kobayashi	2018	106 OA, 12; PA,13; DA, 29; CR, 52	SRI	Water constraints and difficulties in transplanting were two major determinants of SRI adoption/rejection at the study site.	None	Simple linear regression
Indonesia ($n = 6$)						
Ashari et al.	2018	600 (*A*, 300; *N*, 300)	OF	Perception of the usefulness, environmental concern, and perceived ease of use positively and significantly affect the attitude toward organic farming.	The government should design a program that can encourage a favorable attitude toward OF among farmers. Intensive training and improvement of education for the farmers.	Theory of planned behavior (TPB), multiple linear regressions, Likert scale
Kurniati et al.	2021	200	IRL	Income, land area, number of cattle, and farmers' perceptions had a very significant effect on IRL adoption	None	Multinomial logistic regression
Listiana et al.	2020	52	EF	The ability of farmers to adopt environmental innovations is influenced by the level of cosmopolitanism, innovation skills, the support of extension services, and the ease of accessing information technology.	None	Multiple linear regression
Purnomos et al.	2021	40	IRF	Farmers' attitudes, knowledge and skills, infrastructure, and government support have a significant effect on IRF adoption.	Increase farmers' positive attitudes by offering counseling and training on crop-livestock integration organized by the government, private sector, universities, or other institutions.	Multiple linear regression
Widarni et al.	2020	198	IRL	Formal education; frequency of training; farming experience	None	Multinomial logistic regression

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Widadie and Agustono	2015	112 (*A*, 65; *N*, 47)	IRL	Family members, education level, number of cows, farm income, training, and frequency of contact with extension agents are the main determinants	Provide technology extension and demonstration to increase farmers' WTA-integrated farming technology. The government should provide productive aids and inputs that support IRL such as crossbreeding technology and small ruminants development.	Logit regression
Laos ($n = 0$)						
Myanmar ($n = 1$)						
Oo and Usami	2020	315	GAP	Farmers' perception was significantly influenced by gender, education, farmland size, access to credit, income from crop production, contact with extension agents, receiving agricultural information, and getting training in GAPs in rice production.	The implementation of GAPs in rice production should focus mainly on low-income smallholders. The government should reform the credit plan for farmers who wish to accept GAPs in rice production. Extension workers should have regular contact with farmers to enhance farmers' perception of the compatibility of GAPs in rice production.	Binary logit model
Malaysia ($n = 4$)						
Adnan et al.	2017	132	SAP	Farmers' awareness, attitude, subjective norms, and perceived behavioral control have a significant effect on farmer's adoption of SAP. If paddy farmers are more concerned about the environment, they will find adopting SAP more attractive.	Marketing authorities and legal agencies can use reasoning and emotional reactions to develop their communication, instruction, and strategies for potentially overcoming some obstacles toward SAP adoption.	Theory of planned behavior (TPB), technology acceptance model (TAM), structural equation modeling (SEM)

Table 4 (continued)

Country (sum of studies)/author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Adnan et al.	2019	252	GFT	Communication channels, environmental factors, socio-psychological, socioeconomic aspects, innovation attributes, education level, age, participation in farming events, and knowledge and perception of sustainable farming lead to the adoption of GFT among Malaysian paddy farmers.	Policy-makers are advised to concentrate on paddy-related issues, including the eradication of illegal paddy passageways, a quick and reliable way to purchase and prepare harvesting paddy fields, and exceptional support for paddy farmers.	Theory of planned behavior (TPB), technology acceptance model (TAM), diffusion of innovation (DOI), Structural equation modeling (SEM)
Aris and Fatah	2019	50	SRI	Age, educational level, field size, and the role of information and environmental conditions.	SRI extension service should be improved to increase farmer awareness.	Multiple linear regression
Terano et al.	2015	61	GAP	Farmers' attitude and perceived behavioral control toward sustainable agriculture, age, number of protective equipment used, storage of chemical inputs, awareness and knowledge of MyGAP/IPM.	Provide more information, training, and extension to the paddy farmers. Demonstration plots of sustainable practices need to be established.	Multiple linear regression
Philippines ($n = 2$)						
Digal and Placencia	2018	100	OF	Significant factors affecting the adoption decision were gender, level of education, years of farming experience, farm size, yield per hectare during the dry season, and cost per hectare.	Incentives for the farmers for the conversion. Incentives for the consumers to choose alternative food products. Subsidizing organic inputs could increase the likelihood of adoption.	Probit regression
Samoy-Pascual	2021	163 (*A*, 51; *N*, 112)	AWD	Awareness factor did not play a significant role in the farmers' adoption due to the rotational irrigation setup. Farmers' influence on irrigation scheduling, the field water depth less than 5 cm show significant negative effects on AWD adoption. Farmers' perception of water management as an effective weed control method was positively significant.	Fine-turning rotational irrigation schedule. Using decision-support tools, using internet-of-things (IoTs). Improve and rehabilitate the physical infrastructure of the irrigation system.	Probit binary choice model

Table 4 (continued)

Country (sum of studies)/author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Thailand (n = 12)						
Bunbongkarn and Pongquan	2013	129	IF	In the lowlands: the percentage of use of natural fertilizers, income from vegetables, and participation frequency in integrated farming training. In the uplands: number of years of experience in practicing integrated farming, the amount of loans for integrated farming, and water adequacy.	Policy instruments should put emphasis on solving water shortage problems. Encourage farmers to try IF on a small scale initially. Policy instruments should be designed to fit the geographical conditions and to reduce costs. The use of natural fertilizers should be encouraged.	Linear regression
Joblaew et al.	2019	202	GAP	Gender, rice farming experience, household income, agricultural extension officers, attendance of rice production technology training, and problems relating to the project.	Encourage farmers to attend training and farmer groups where knowledge and experience can be exchanged.	Logistic regression
Kerdsriserm et al.	2016	30	OF	Participation in training and gender were found to have a positive influence on OF adoption. Women farmers were more likely to adopt OF.	Providing training on organic rice farming to conventional farmers can motivate them to adopt organic rice farming practices.	Multiple regression
Pornpratansombat et al.	2011	180 (A, 90; N, 90)	OF	Organic farmers depend more on the income from agricultural activities than conventional farms. Water accessibility, the ability to seek higher farm-gate prices, and attitudes toward conventional problems are highly significant for OF adoption.	Off-farm work, price difference, water accessibility, credit support, and attitudes toward OF may be controllable by policies.	Cox model
Senanuch et al.	2022	253	HPRS	Positive effects: educational level, farming knowledge, understanding of benefits, additional training, water sources, workforce sharing, and access to advisory services. Negative effects: complexity of the HPRS and land tenure security	Emphasizing the practicality, and affordability of HRPS practices to farmers. Promoting on-farm collective action and workforce sharing among peer farmers. Improving the meetings between advisors and farmers.	The hurdle probit, tobit regression

Table 4 (continued)

Country (sum of studies)/author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Salaisook et al.	2020	150	SLM	Reasons for SLM adoption: Ownership of farmland, major income from farming, farmers believe that SLMs have various benefits compared to the costs incurred, desire to improve farming practices, and attend training sessions. Off-farm employment led to a decrease in the adoption of SLM practices because most of the SLM practices required time.	Focusing on extension activities. Identifying and promoting types of farm structure and management that are capable of incentivizing farmers to spend time and effort on SLM farming.	Probit and tobit regression models
Sereenonchai and Arunrat	2022	240	RSM	Perceived pro-environmental personal norms, perceived cues to rice straw utilization, perceived behavioral control, perceived severity of rice straw burning, perceived ascription of responsibility, and the perceived benefits of rice straw utilization were significantly negatively influenced by burning.	Promoting action knowledge and self-efficacy at the group level, promoting perceived responsibility via self-awareness and self-commitment, and providing convenient channels of communication to farmers to have more effective non-burning rice straw and stubble management.	VBN, TPB, and HBM; structural equation modeling; stepwise multiple linear regression analysis
Seerasarn et al.	2020	100 (*A*, 67; *N*, 33)	OF	Farming experience, land ownership, assets, access to credit from a local source, and extension service.	Helping finance farmers to own their own property, local cooperatives provide favorable low interests loans to farmers. Providing funding for more local training to farmers.	Binary logistic regression
Suwanmaneepong et al.	2020	108 (*A*, 58; *N*, 50)	OF	Positive influence: education, farming experience, environmental concern. Negative influence: age, farm size.	Increasing awareness of farmers about the environmental impact is important for the government and related organizations in designing effective strategies to promote OF.	Binary logistic regression

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Srisopaporn et al.	2015	244	GAP	Labor constraints are the most important factor related to the non-adoption of GAP. Training and government contacts were essential in keeping the farmers in the program.	A better policy that can control and regulate 'land rent prices' could potentially improve and encourage farmers who are renting land to adopt this certification. Promote labor-saving techniques.	Probit model, bivariate probit model
Supaporn et al.	2013	120	RSM	Farmer's education level and the number of training programs attended have a positive influence on RSM adoption. Farmers' attitudes toward Insufficient labor, lack of knowledge, and the difficulty in making the compost negatively influence RSM adoption.	Additional labor is needed. The government should increase the number of training programs.	Logit regression
Yanakittkul and Aungvaravong	2020	849 (*A*, 448; *N*, 401)	OF	Conventional farmers have a negative attitude toward organic rice farming.	The government should implement a policy to increase understanding and promote the benefits of organic rice farming and increase awareness of the risks and dangers of conventional agriculture. Encourage conventional farmers to join the organic rice member group and to promote the knowledge of techniques for growing certified organic rice and provide incentives.	SEM
Vietnam ($n = 13$)						
Bosma et al.	2012	94	IRF	Households with neighboring irrigated fields and ponds, better access to financial capital, and more know-how of rice and fish culture and their integration were more likely to adopt rice–fish systems.	Extension service educational programs are advised to use participatory technology development and farmer's field school approaches.	Binary logistic regression, fuzzy logic

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Connor et al.	2020	111	RSM	Benefit perception, risk perception, climate change knowledge, farm size, support expectations from the government and institutions, and membership of cooperatives have impacts on farmers' rice straw management practices.	Knowledge of the physical aspects of climate change is essential to create tailored interventions for farmers to practice SAPs. For successful implementation of new practices, it will be important to address the following factors: risk and benefit perceptions, knowledge about climate change, or account for limiting factors such as farm size or multiple crops per year.	Multiple regression models
Connor et al.	2021	465	1M5R	Almost all farmers followed the requirements of pesticide reduction, post-harvest loss reduction, and the use of certified seeds. However, farmers had problems reducing their fertilizer use, water use, and seed rate. The ease of implementation, education, satisfaction, and non-rice income are the main drivers for adopting the whole package.	It is important to evaluate each component separately and not as a whole for such complex programs as 1M5R.	Binary logistic regressions
Dung et al.	2018	420 (*A*, 260; *N*, 160)	1M5R, IPM	SAT (1M5R, IPM, HTA, AT4.0); farmers' knowledge, education, farm size, membership of cooperative, extension, and access to the market significantly affect the adoption of SATs.	The government needs to focus on vocational training for farmers emphasizing innovative farming techniques, equipment, and products. The government needs to revise the land law to encourage land accumulation for large-scale production. Investments for improving the quality of social capital. Enhancing the quality of the extension system. Strengthening the input and product markets.	Binary logit model

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Dung	2020	350	CSA	Perceived climate change impact, educational level, farmland size, access to credit, social capital, access to extension, secure farmland tenure, and restricted access to market.	Encourage farmland expansion, promote agricultural modernization, widen access to formal credit programs and reduce transaction costs, expand the activities of microfinance institutions to more effectively reach the poor and vulnerable groups, improve social capital, intensify the promotion of CSA measures, and improve farmers' awareness of fostering the economic, social and environmental effectiveness of CSA through mass media. Promote and improve vocational training for farmers through the extension service system.	Multinomial logit model
Ha and Bac	2021	214 (*A*, 118; *N*, 96)	CSA	Education, access to information, and rate of rice income.	Improve the following factors could enhance the expansion of CSA practices: formal education of household heads, access to extension services, proportion of rice income	Logit regression model
Hoang	2021	215 (*A*, 78; *N*, 137)	OF	(1) Younger female farmers participating in credit/training programs and community-based organizations, with a higher level of education; (2) larger household size; (3) more experience in rice farming; and (4) growing mixed crops	A combination of demographic and socio-economic characteristics of rice farmers should be considered when promoting organic farming.	Descriptive and inferential statistics, binary logistic regression analysis
Nguyen and Hung	2022	239 (*A*, 140; *N*, 99)	SRI	Age, amount of family labor available, access to credit, and number of plots.	Focus more on young farmers and implement a credit program for farmers. More training for the SRI.	Binary logistic model

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Song et al.	2020	200	SLM	Risk aversion and farming experience have negative effects. Farm size and knowledge of SLM have positive effects on SLM adoption.	Increase SLM adoption through better training, increasing the cultivated farmland, farm clustering, encouraging farmers to join farmers' organizations, introducing and subsidizing labor-saving technologies, making credit accessible, improving the insurance market, and demonstrating plots for SLM practices.	2SLS probit model, IV, and probit regression model
Tien et al.	2022	165	OF	(1) Input policies to support organic rice production, (2) usefulness comparison between organic and conventional rice production, (3) farmers' awareness of controlling input and output of organic rice production activities, (4) farmers' attitudes toward organic rice, (5) influence of family members and farmer groups, and (6) risk perception	The government should strengthen policies (1) to support production inputs for organic rice farmers, (2) to promote OF frequently in the mass media, (3) to establish groups of organic rice farmers for better communication, and (4) to execute agricultural contracts to link production and consumption processes.	Theory of planned behavior (TPB) and factor analysis
Tho et al.	2021	380 (*A*, 140; *N*, 240)	1M5R	Education level, training class attendance, and cooperative membership are the key factors driving households' decision to practice the 1M5R technique in their fields.	Encourage paddy farmers to continue reducing the seeds sown to meet the recommended amount (80–100 kg/ha). Encourage conventional farmers to visit the field of successful examples. Provide certificates to 1M5R products for both domestic and export demands.	Propensity score matching and the probit model

Table 4 (continued)

Country (sum of studies)/ author(s)	Year	Sample size	Type of SAPs	Findings	Recommendations	Theory/methods
Tran et al.	2019	579	CSA	Factors that influence the adoption decision: gender, age, number of family workers, climate-related factors, farm characteristics, distance to markets, institutional factors such as access to climate information, confidence in the know-how of extension workers, membership in social/agricultural groups, and attitude toward risks.	Provide security of the tenure and facilitate the operation of the land rental markets. Ensure that the extension workers have the necessary technical know-how to inspire farmers' confidence in their technical capability. Provide more training to farmers through field research/experiments and evidence-based critical climate change information.	Multinomial logit selection model
Tu et al.	2018	202	SAP	Positive effects on adoption: membership in agricultural cooperatives or clubs, perception of biodiversity losses, perceived ease of use, farmer experience, perceived difference in selling price. Negative effects on adoption: risk perception and number of paddy plots. Farmers with larger farms but fewer plots are the most feasible group to adopt eco practices.	Policy-makers should create an incentive mechanism to encourage farmers to join farmer organizations. Policy-makers should inform farmers about mitigating risks such as adverse climatic impacts, polluted water, and other environmental threats. Technical training courses and other information-sharing meetings should be required to introduce farmers to the benefits of eco practices.	Generalized ordered logit regression

Table 5 Factors that have statistical significance on the adoption of SAPs. *Sig (+)* positive significant, *Sig (−)* negative significant, *N-Sig* non-significant; (−), the variable is always not significant; *the variable is always negatively significant; **has a mixed significance; ***the variable is always positively significant.

Factors					
Socio-demographic characteristics (8)	Sig(+)	Sig(−)	N−Sig	Total	
Age	2	6	13	21	**
Education level	15	1	10	26	**
Farming experience	8	1	7	16	**
Gender	2	5	6	13	**
Household size	3	1	7	11	**
Local leadership	0	0	1	1	–
Other occupation	0	0	1	1	–
SAP farming experience	1	0	1	2	**
Farm management factors (53)					
Active labor force	0	0	1	1	–
Access to market	0	1	0	1	*
Availability of inputs	0	0	1	1	–
Distance to the sell market for the products	1	2	0	3	**
Distance to buy the inputs	1	1	0	2	**
Distance from home to farm	0	0	1	1	–
Drought	1	0	0	1	***
Decision-making by the couple	0	1	0	1	*
Decision-making by female only	0	1	0	1	*
Environmental condition practicing SRI	0	1	0	1	*
Family labor	1	0	3	4	**
Farm size/plot size	8	4	13	25	***
Farmers can decide on their irrigation schedule	0	0	1	1	–
Farmer owned Machinery	0	0	2	2	–
Farm is actively irrigated	0	0	1	1	–
Growing mixed crops	1	0	0	1	***
Growing vegetables	1	0	0	1	***
Having livestock on farm	2	1	0	3	**
Having farm pond	1	0	0	1	***
Having plans for the farm	1	0	0	1	***
Having own water resources	1	0	0	1	***
If field water depth after irrigation is less than 5 cm	0	1	0	1	*
If farmer can influence the irrigation scheduling	0	1	0	1	*
If there is another source of irrigation	0	0	1	1	–
If there is a rotational irrigation scheduling followed	0	0	1	1	–
If the manner of irrigation is plot-to-plot	0	0	1	1	–
If farmer monitors his field during irrigation	0	0	1	1	–
If problem is faced relating to the SAP project	0	1	0	1	*
Infrastructure	1	0	0	1	***
Land ownership	4	2	4	10	**
Location	0	0	2	2	–
Number of plots	3	0	2	5	**
Number of labors	2	1	7	10	**
Number of livestock	2	0	1	3	**
Number of protection equipment when applying chemical input (1 = above 3 equipment, 0 = below 3 equipment)	1	0	0	1	***
Only hired labor	0	1	0	1	*
Only growing rice	0	0	1	1	–

Table 5 (continued)

Ownership of livestock	0	0	1	1	–
Pest and disease	1	1	0	2	**
Percentage of the use of natural fertilizers	1	0	0	1	***
Preparation of Land by machine	0	0	1	1	–
Rainfall index	1	1	0	2	**
Soil fertility (3 = highly fertile, 2 = moderately fertile, 1 = poorly fertile)	1	1	0	2	**
Slop of plots (1 = deep, 2 = medium, 3 = flat)	1	0	0	1	***
Storing chemical inputs in a safe place away from fire and children	1	0	0	1	***
The level of cosmopolitanism	1	0	0	1	***
The level of application of SAP paddy cultivated innovations	1	0	0	1	***
Timing of irrigation when no visible water on the soil surface	0	0	1	1	–
Toposequence	0	0	1	1	–
Water adequacy	1	0	0	1	***
Water availability	1	0	1	2	**
Waterlogg	1	0	0	1	***
Economic factors (18)					
Amount of loans	1	0	1	2	**
Access to credit	5	1	4	10	**
Borrow agricultural loans	0	0	1	1	–
Cost per hectare	0	1	0	1	*
Cost of production	0	0	1	1	–
Expenses on food	0	0	1	1	–
Farm gate price	1	0	0	1	***
Farm income per year	5	0	0	5	***
Having asset	0	0	1	1	–
Household savings	0	0	1	1	–
Income only from rice (1 = yes, 0 = otherwise)	0	1	1	2	**
Income from vegetables (1 = yes, 0 = otherwise)	1	0	0	1	***
Income from fruits (1 = yes, 0 = otherwise)	0	0	1	1	–
Income from livestock (1 = yes, 0 = otherwise)	0	0	1	1	–
Off-farm income per year	2	1	4	7	**
Profit per hectare	0	0	1	1	–
Proportion of rice income in total income	1	0	0	1	***
Yield per hectare	1	1	1	3	**
Institutional factors (12)					
Access to extension	6	0	2	8	**
Access to climate change information	1	0	0	1	***
Access to information (including climate change)	3	1	1	5	**
Access to irrigation	1	0	2	3	**
Frequencies of government contact	1	0	0	1	***
Frequency of visits of extension workers	2	0	1	3	**
Frequency of contact with traders	1	0	1	2	**
Membership of cooperative	5	0	5	10	**
Membership of farmer's association	1	0	5	6	**
Membership of seed growers' association	0	0	1	1	–
Participation in SAP training	6	1	2	9	**
Participation frequency in integrated farming training	3	0	0	3	***

Table 5 (continued)

Social factors (1)					
Neighbors are practicing SAPs	0	0	1	1	–
Behavioral/psychological factors (45)					
Attitude toward to risk	1	0	1	2	**
Awareness of SAP/GAP/IPM/AWD	2	1	0	3	**
Attitude toward the SAP benefits	2	0	1	3	**
Attitude toward integrated organic crop-livestock farming	1	0	0	1	***
Attitude toward organic farming	2	0	0	2	***
Attitude toward green fertilizer technology	1	0	0	1	***
Attitude toward insufficient labor	1	1	0	2	**
Attitude toward lack of knowledge on straw compost	0	2	0	2	*
Attitude toward sufficient support from government	2	0	1	3	**
Attitude toward difficulty in making straw compost	0	1	0	1	*
Attitude toward support from the SAP project	0	0	2	2	–
Attitude toward problem of conventional farming	1	0	0	1	***
Comparative usefulness of behavior	1	0	0	1	***
Complexity of the SAPs	1	1	0	2	**
Environmental concerns	2	0	0	2	***
Expected cost reduction	1	0	0	1	***
Experience of negative shock	0	0	1	1	–
Farmers' expectation of 1M5R package (SAP)	0	0	1	1	–
Farmers' satisfaction of 1M5R package (SAP)	0	0	1	1	–
Group norm	2	0	0	2	***
Knowledge about climate change	2	0	0	2	***
Knowledge about SAP/GAP/IPM/integrated	7	0	0	7	***
Mass media	1	0	0	1	***
Moral obligation	1	0	1	2	**
Observability	1	0	0	1	***
Perceived pro-environmental personal norms	0	1	0	1	*
Perceived cues to rice straw utilization	0	1	0	1	*
Perceived ease of use	1	0	0	1	***
Perceived receipt of outside support	0	0	1	1	–
Perceived behavior control	3	1	1	5	**
Perceived severity of rice straw burning	0	1	0	1	*
Perceived ascription of responsibility	0	1	0	1	*
Perceived benefits of rice straw utilization	0	1	0	1	*
Perceived benefits of current option	1	0	0	1	***
Perceived benefits of eco practices	0	0	1	1	–
Perceived selling price of output	1	0	0	1	***
Perceived output level	0	0	1	1	–
Perceived higher price for their products	0	0	1	1	–
Perceived cost	1	0	0	1	***
Perceived utility	0	0	1	1	–
Perceived awareness	1	0	0	1	***
Perception of rice farming impact on environment	0	0	1	1	–
Perception toward biodiversity	1	0	0	1	***
Perception toward water pollution	0	0	1	1	–
Perception toward water management as a good weed control method	1	0	0	1	***
Perception of integrated farming	1	0	0	1	***

Table 5 (continued)

Risk perceptions	3	1	0	4	**
Risk aversion	0	1	0	1	*
Subjective knowledge	0	0	1	1	–
Subjective norm	2	0	1	3	**
Support expectations from the government and institutions	0	0	1	1	–
Trialability	1	0	0	1	***
Understanding the benefit of SAP	1	0	0	1	***

Authors' contributions Sheng-Han-Erin Chang conducted the analysis and wrote the manuscript. Emmanuel O. Benjamin and Johannes Sauer provided supervisory support with the conceptual framework and commented on the manuscript.

Funding Open Access funding enabled and organized by Projekt DEAL.

Data availability The data may be obtained from the authors upon reasonable request.

Code availability The code may be obtained from the authors upon reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Adnan N, Nordin SM, Baker ZBA (2017) Understanding and facilitating sustainable agricultural practices: a comprehensive analysis of adoption behaviour among Malaysian paddy farmers. Land Use Policy 68:372–382. https://doi.org/10.1016/j.landusepol.2017.07.046

Adnan N, Nordin SM, Anwar A (2019) Transition pathways for Malaysian paddy farmers to sustainable agricultural practices: an integrated exhibiting tactics to adopt green fertilizer. Land Use Policy 90:104255. https://doi.org/10.1016/j.landusepol.2019.104255

Ali J, Yusof N, Abd Aziz FS (2018) Factors influencing farmers' perceptions and behavior toward pesticide use in Malaysia. Int J of Soc Econ 45(5):775–791. https://doi.org/10.1108/IJSE-11-201600304

Aris NFM, Fatah FA (2019) Cost and return analysis of system of rice intensification (SRI): evidence from major rice producing areas in Malaysia. Int J Supply Chain Manag 8(3):541–546. https://api.semanticscholar.org/CorpusID:212804276. Accessed 01.02.2022

Arsil P, Tey YS, Brindal M, Ardiansyah, Sumarni E, Masrukhi (2022) Perceived attributes driving the adoption of system of rice intensification: The Indonesian farmers' view. Open Agric 7(1). https://doi.org/10.1515/opag-2022-0080

Ashari SJ, Mohammed Z, Terano R (2018) Paddy farmer's perception and factors influencing attitude and intention on adoption of organic rice farming. Int Food Res J 25:135–145

Atieno M, Herrmann L, Nguyen HT, Phan HT, Nguyen NK, Srean P, Than MM, Zhiyong R, Tittabutr P, Arawan S et al (2020) Assessment of biofertilizer use for sustainable agriculture in the Great Mekong Region. J Environ Manage 275:111300. https://doi.org/10.1016/j.envman.2020.111300

Begho T, Glenk K, Anik AR, Eory V (2022) A systematic review of factors that influence farmers' adoption of sustainable crop farming practices: lessons for sustainable nitrogen management in South Asia. J Sus Agric Environ 1(2):149–160. https://doi.org/10.1002/sae2.12016

Berg H (2002) Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam – economic and ecological considerations. Ecol Econ 41(1):95–107. https://doi.org/10.1016/S0921-8009(02)00027-7

Bulkis S, Rahmadanih R, Nasruddin A (2020) Rice farmers' adoption and economic benefits of integrated pest management in south Sulawesi Province, Indonesia. J Agric Ext 24(2). https://doi.org/10.4314/jae.v24i2.4

Bosma RH, Nhan DK, Udo HMJ, Kaymak U (2012) Factors affecting farmers' adoption of integrated rice-fish farming systems in the Mekong delta. Vietnam. Rev Aquac 4:178–190. https://doi.org/10.1111/j.1753-5131.2012.01069.x

Bunbongkarn S, Pongquan S (2013) Adoption of integrated farming in Thailand delivered by the royal development study centres. Outlook Agric 42(3):209–214. https://doi.org/10.5367/oa.2013.0132

Castella JC, Kibler JF (2015) Towards an agroecological transition in Southeast Asia: cultivating diversity and developing synergies. GRET, Vientiane, Lao PDR. https://gret.org/wp-content/uploads/2021/12/AE-Book_GRET_VFF_web.pdf. Accessed 03.02.2022

Cho KM, Zoebisch MA (2003) Land-Use Changes in the Upper Lam Phra Phloeng Watershed, Northeastern Thailand: characteristics and driving forces. J Agric Rural Dev Trop Subtrop 104(1):15–29

Connor M, de Guia AH, Quilloy R, Nguyen HV, Gummert M, Sander BO (2020) When climate change is not psychologically distant – factors influencing the acceptance of sustainable farming practices in the Mekong River Delta of Vietnam. World Dev Perspectiv 18:100204. https://doi.org/10.1016/j.wdp.2020.100204

Connor M, de Guia AH, Pustika AB, Sudarmaji KM, Hellin J (2021) Rice farming in Central Java, Indonesia – adoption of sustainable farming practices, impacts and implications. Agron 11(5):881. https://doi.org/10.3390/agronomy11050881

Defrancesco E, Gatto P, Mozzato D (2018) To leave or not to leave? understanding determinants of farmers' choice to remain in or abandon agri-environmental schemes. Land Use Policy 76:460–470. https://doi.org/10.1016/j.landusepol.2018.02.026

Dessart F, Barreiro-Hurle J, van Bavel R (2019) Behavioural factors affecting the adoption of sustainable farming practices: a policy-oriented review. Eur Rev Agric Econ 46(3):417–471. https://doi.org/10.1093/erae/jbz019

Devkota KP, Pasuquin E, Elmido-Mabilangan A, Dikitanan R, Singleton GR, Stuart AM et al (2019) Economic and environmental indicators of sustainable rice cultivation: a comparison across intensive irrigated rice cropping systems in six Asian countries. Ecol Indic 105:199–214. https://doi.org/10.1016/j.ecolind.2019.05.029

Digal LN, Placencia SGP (2018) Factors affecting the adoption of organic rice farming: the case of farmers in M'lang, North Cotabato, Philippines. Org Agr 9:199–210. https://doi.org/10.1007/s13165-018-0222-1

Doi R, Mizoguchi M (2013) Feasibility of system of rice intensification practices in natural and socioeconomic contexts in Thailand. Int J Sustain Dev World Ecol 20(5):433–441. https://doi.org/10.1080/13504509.2013.801002

Duc Truong D, Tho Dat T, Hug Huan L (2022) Factors affecting climate-smart agriculture practices adaptation of farming households in coastal central Vietnam: The case of Ninh Thuan Province. Front Sustain Food Syst 6:790089. https://doi.org/10.3389/fsufs.2022.790089

Dung LT, Ho DP, Hiep NTK., Hoi PT (2018) The determinants of rice farmers' adoption of sustainable agricultural technologies in the Mekong Delta, Vietnam. Asian J Appl Econ 25(2):55–69. https://so01.tci-thaijo.org/index.php/AEJ/article/view/179746. Accessed 03.02.2022

Dung LT (2020) Factors influencing farmers' adoption of climate-smart agriculture in rice production in Vietnam's Mekong Delta. Asian J Agric Dev 17(1):109–124. https://doi.org/10.37801/ajad2020.17.1.7

Flor RJ, Maat H, Hadi BAR, Then R, Kraus E, Chhay K (2020) How do stakeholder interactions in Cambodian rice farming villages contribute to a pesticide lock-in? Crop Prot 135:104799. https://doi.org/10.1016/j.cropro.2019.04.023

Foguesatto CR, Borges JAR, Talamini E, Machado JAD (2020) A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. Sci total Environ 729:138831. https://doi.org/10.1016/j.scitotenv.2020.138831

Fritz M, Grimm M, Keilbart P, Laksmana DD, Luck N, Padmanabhan M, Subandi N, Tamtomo K (2021) Turning Indonesia organic: insights from transdisciplinary research on the challenges of a societal transformation. Sustainability 13:13011. https://doi.org/10.3390/su132313011

Guo Q, Ola O, Benjamin EO (2020) Determinants of the adoption of sustainable intensification in Southern African farming systems: a meta-analysis. Sustainability 12(8):3276. https://doi.org/10.3390/su12083276

Ha TM, Bac HV (2021) Effects of climate-smart agriculture adoption on performance of rice farmers in Northeast Vietnam. Asian J Agric Rural Dev 11(4):291–301. https://doi.org/10.18488/journal.ajard.2021.114.291.301

IPCC (2007) Climate Change 2007: synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change. In: Pachauri RK, Reisnger A (eds). IPCC, Geneva, p 104. https://www.ipcc.ch/report/ar4/syr/. Accessed 04.02.2022

Joblaew P, Sirisunyaluck R, Kanjina S, Chalermphol J, Prom-u-thai C (2019) Factors affecting farmers' adoption of rice production technology from the collaborative farming project in Phrae province, Thailand. Int J Agric Technol 15 (6):901–912. https://www.cabdirect.org/cabdirect/abstract/20203018728. Accessed 01.02.2022

Jones KW, Powlen K, Roberts R, Shinbrot X (2020) Participation in payments for ecosystem programs in the global south: a systematic review. Ecosyst Serv 45:101159. https://doi.org/10.1016/j.ecoser.2020.101159

Josue-Canacan DR (2022) Adoption of integrated pest management (IPM) technologies in Southern Philippines: constraints and motivations. Int J Agric Technol 18 (1):179–192. http://www.ijat-aatsea.com/pdf/v18_n1_2022_January/12_IJAT_18(1)_2022_Josue-Canacan,%20D.%20R.(143).pdf. Accessed 16 May 2023

Kaur M, Malik DP, Malhi GS, Sardana V, Bolan NS, Lal R, Siddique KHM (2022) Rice residue management in the Indo-Gangetic plains for climate and food security. A Review. Agron Sustain Dev 42:92. https://doi.org/10.1007/s13593-022-00817-0

Keck M, Hung DT (2019) Burn or bury? A comparative cost-benefit analysis of crop residue management practices among smallholder rice farmers in northern Vietnam. Sustain Sci 14:375–389. https://doi.org/10.1007/s11625-018-0592-z

Kerdsriserm C, Suwanmaneepong S, Mankeb P (2016) Factors affecting adoption of organic rice farming in sustainable agriculture network, Chachoengsao Province, Thailand. Int J Agric Technol 12(7.1):1227–1237. https://api.semanticscholar.org/CorpusID:211098478. Accessed 16 May 2023

Kurniati N, Sukiyono K, Purmini P, Sativa MO (2021) Adoption level of integrated farming system based on rice-cattle and its determinants related to sustainable agriculture. The 1st International Conferences on Bioenergy and Environmentally Sustainable Agriculture Technology 226:00034. https://doi.org/10.1051/e3sconf/202122600034

Lee YH, Kobayashi K (2018) Assessing the acceptance of the system of rice intensification among farmers in rainfed lowland rice region of Cambodia. Paddy Water Environ 16:533–541. https://doi.org/10.1007/s10333-018-0646-y

Limnirankul B and Gypmantasiri P (2012) Incorporating agro-biodiversity to market-oriented organic rice in northern Thailand: an enabling innovation process and achievement. Agric Nat Resour 11(1). http://cmuir.cmu.ac.th/jspui/handle/6653943832/52020. Accessed 16 May 2023

Linquist BA, Anders MM, Adviento-Borbe MA, Chaney RL, Nalley LL, da Rosa EF, van Kessel C (2015) Reducing greenhouse gas emissions, water use, and grain arsenic levels in rice systems. Glob Change Biol 21(1):407–417. https://doi.org/10.1111/gcb.12701

Listiana I, Hudoyo A, Prayitno RT, Mutolib A, Yanfika H, Rahmat A (2020) Adoption level of environmentally friendly paddy cultivated innovation in Pringsewu district, Lampung province. Indonesia. J Phys Conf Ser 1467:012025. https://doi.org/10.1088/1742-6596/1467/1/012025

Ly P, Jensen JS, Bruun TB, Rutz D, de Neergaard A (2012) The system of rice intensification: adapted practices, reported outcomes and their relevance in Cambodia. Agric Syst 113:16–27. https://doi.org/10.1016/j.agsy.2012.07.005

Mandal KG, Misra AK, Hati KM, Bandyopadhyay KK, Ghosh PK, Mohanty M (2004) Rice residue-management options and effects on soil properties and crop productivity. J Food Agric Environ 2(1):224–231

Mao M, Tongdeelert P, Chumjai P (2008) The adoption of the system of rice intensification (SRI) in Tram Kak District, Takeo Province, Cambodia: the case study of leading farmers. Kasetsart J

Soc Sci 29(3):303–316. Retrieved from https://so04.tci-thaijo.org/index.php/kjss/article/view/246478. Accessed 16 May 2023
Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group (2009) Preferred reporting items for systematic review and meta-analysis: the PRISMA statement. PLoS Med. 6(7):e1000097. https://doi.org/10.1371/journal.pmed.1000097
Mills J, Gaskell P, Ingram J, Dwyer J, Reed M, Short C (2017) Engaging farmers in environmental management through a better understanding of behaviour. Agric Human Values 34:283–299. https://doi.org/10.1007/s10460-016-9705-4
Mungkung R, Gheewala SH, Silalertruksa T, Dangsiri S (2019) Water footprint inventory database of Thai rice farming for water policy decisions and water scarcity footprint label. The Int J Life Cycle Assess 24(12):2128–2139. https://doi.org/10.1007/s11367-019-01648-0
Mungkung R, Sitthikitpanya S, Chaichana R, Bamrungwong K, Santitaweeroek Y, Jakrawatana N, Silalertruksa T, Gheewala SH (2022) Measuring sustainability performance of rice cultivation in Thailand using sustainable rice platform indicators. Int J Agric Sustain 20(7):1278–1293. https://doi.org/10.1080/14735903.2022.2105008
Mutert E, Fairhurst TH (2002) Developments in rice production in Southeast Asia. Better Crops Int 15:12–17. https://api.semanticscholar.org/CorpusID:56153388. Accessed 02.02.2022
Neang M, Méral P, Aznar O, Déprés C (2017) Diversity of rice cropping systems and organic rice adoption in agro-ecosystem with high risk of flood in Cambodia. Int J Agric Resour Gov Ecol 13(4):351–370. https://doi.org/10.1504/IJARGE.2017.088402
Nguyen HTT, Hung PX (2022) Determinants of system of rice intensification adoption and its impacts on rice yield in the upland region of Central Vietnam. Asian J Agric Rural Dev 12(4):306–315. https://doi.org/10.55493/5005.v12i4.4677
Nguyen VH, Stuart AM, Nguyen TMP, Pham TMH, Nguyen NPT, Pame ARP, Sander BO, Gummert M, Singleton GR (2022) An assessment of irrigation rice cultivation with different crop establishment practices in Vietnam. Sci Rep 12:401. https://doi.org/10.1038/s41598-021-04362-w
Olabisi LS, Wang RQ, Ligmann-Zielinska AL (2015) Why don't more farmers go organic? using a stakeholder-informed exploratory agent-based model to represent the dynamics of farming practices in the Philippines. Land 4(4):979–1002. https://doi.org/10.3390/land4040979
Oo SP, Usami K (2020) Farmers' perception of good agricultural practices in rice production in Myanmar: a case study of Myaungmya District. Ayeyarwady Region. Agric 10:249. https://doi.org/10.3390/agriculture10070249
Pham HG, Ghuah SH, Feeny S (2021) Factors affecting the adoption of sustainable agricultural practices: findings from panel data for Vietnam. Ecol Econ 184:107000. https://doi.org/10.1016/j.ecolecon.2021.107000
Premier R, Ledger S (2006) Good agricultural practices in Australia and Southeast Asia. HortTechnology 16(4):552–555. https://doi.org/10.21273/HORTTECH.16.4.0552
Priya, Singh SP (2022) Factors influencing the adoption of sustainable agricultural practices: a systematic literature review and lesson learned for India, Forum Soc Econ. https://doi.org/10.1080/07360932.2022.2057566
Price JC, Leviston Z (2014) Predicting pro-environmental agricultural practices: the social, psychological and contextual influences on land management. J Rural Stud 34:65–78. https://doi.org/10.1016/j.jrurstud.2013.10.001
Pornpratansombat P, Bauer B, Boland H (2011) The adoption of the organic rice farming in northeastern Thailand. J Org Syst 6(3). https://www.organic-systems.org/journal/Vol_6(3)/pdf/JOS_6(3)_2011_04-12_Pornpratansombat.pdf. Accessed 01.02. 2022
Purnomo SH, Sari AI, Emawati S, Rahaya ET (2021) Factors influencing the adoption of integrated crop-livestock to support land conservation of organic agriculture in Mojosongo area, Karanganyar, Indonesia. IOP Conf.Ser.: Earth Environ Sci 724:012049. https://doi.org/10.1088/1755-1315/724/1/012049
Romasanta RR, Sander BO, Gaihre YK, Alberto MC, Gummert M, Quilty J, Nguyen VH, Castalone AG, Balingbing C, SandroCorrea JT Jr, Wassmann R (2016) How does burning of rice straw affect CH4 and N2O emissions? A comparative experiment of different on-field straw management practices. Agric Ecosyst Environ 239:143–153. https://doi.org/10.1016/j.agee.2016.12.042
Rusli NM, Noor ZZ, Taib SM, Han PC (2018) Water footprint assessment of rice production in Malaysia using LCA approach. J Energy and Safety Technol 1(2). https://doi.org/10.11113/jest.v1n2.18
Salaisook P, Faysse N, Tsusaka TW (2020) Reasons for adoption of sustainable land management practices in a changing context: a mixed approach in Thailand. Land Use Policy 96:104676. https://doi.org/10.1016/j.landusepol.2020.104676
Samoy-Pascual K, Yadav S, Evangelista G, Burac MA, Rafael M, Cabangon R, Tokida T, Mizoguchi M, Regalado MJ (2021) Determinants in the adoption of alternative wetting and drying technique for rice production in a gravity surface irrigation system in the Philippines. Water 14(1):5. https://doi.org/10.3390/w14010005
Sapbamrer R (2018) Pesticide use, poisoning, and knowledge and unsafe occupational practices in Thailand. New Solut 28(2):283–302. https://doi.org/10.1177/1048291118759311
Sapbamrer R, Thammachai A (2021) A systematic review of factors influencing farmers' adoption of organic farming. Sustainability 13:3842. https://doi.org/10.3390/su13073842
Seerasarn N, Miller S, Wanaset A (2020) Transitioning to organic rice farming in Thailand: drivers and factors. Asian J Agric Rural Dev 10(3):740–748. https://doi.org/10.18488/journal.ajard.2020.103.740-748
Senanuch C, Tsusaka TW, Datta A, Sasaki N (2022) Improving hill farming: from maize monocropping to alternative cropping systems in the Thai highlands. Land 11(1):132. https://doi.org/10.3390/land11010132
Serebrennikov D, Thorne F, Kallas Z, McCarthy SN (2020) Factors influencing adoption of sustainable farming practices in Europe: a systemic review of empirical literature. Sustainability 12(22):9719. https://doi.org/10.3390/su12229719
Sereenonchai S, Arunrat N (2022) Farmers' perceptions, insight behavior and communication strategies for rice straw and stubble management in Thailand. Agronomy 12(1):200. https://doi.org/10.3390/agronomy12010200
Settele J, Heong KL, Kühn I, Kloty S, Spangenberg JH, Arida G et al (2018) Rice ecosystem services in South-east Asia. Paddy Water Environ 16(2):211–224. https://doi.org/10.1007/s10333-018-0656-9
Silalertruksa T, Gheewala SH, Mungkung R, Nilsalab P, Lecksiwilai N, Sawaengsak W (2017) Implications of water use and water scarcity footprint for sustainable rice cultivation. Sustainability 9(12):2283. https://doi.org/10.3390/su9122283
Singh Y, Sharma S, Kumar U, Sihag P, Balyan P, Singh KP, Dhankher OP (2024) Strategies for economic utilization of rice straw residues into value-added by-products and prevention of environmental pollution. Sci Total Environ 901:167714. https://doi.org/10.1016/j.scitotenv.2023.167714
Somasundram C, Razali Z, Santhirasegaram V (2016) A review on organic food production in Malaysia. Hortic 2(3):12. https://doi.org/10.3390/horticulturae2030012
Song NV, Guong HN, Huyen VN, Ranola RF (2020) The determinants of sustainable land management adoption under risks in upland

area of Vietnam. Sustain Futures 2:100015. https://doi.org/10.1016/j.sftr.2020.100015
Srisopaporn S, Jourdain D, Perret SR, Shivakoti G (2015) Adoption and continued participation in a public good agricultural practices program: the case of rice farmers in the Central Plains of Thailand. Technol Forecast Soc Change 96:242–253. https://doi.org/10.1016/j.techfore.2015.03.016
Stuart AM, Pame ARP, Vithoonjit D, Viriyangkura L, Pithuncharurnlap J, Meesang N, Suksiri P, Singleton GR, Lampayan RM (2018) The application of best management practices increases the profitability and sustainability of rice farming in the central plains of Thailand. Field Crops Res 220:78–87. https://doi.org/10.1016/j.fcr.2017.02.005
Suh J (2015) An institutional and policy framework to foster integrated rice-duck farming in Asian developing countries. Int J Agric Sustain 13(4):294–307. https://doi.org/10.1080/14735903.2014.975480
Sujianto GE, Saptana S, Darwis V, Ashari SM, Ariningsih E, Saliem HP, Mardianto SM (2022) Farmers' perception, awareness, and constraints of organic rice farming in Indonesia. Open Agric 7:284–299. https://doi.org/10.1515/opag-2022-0090
Supaporn P, Kobayashi T, Supawadee C (2013) Factors affecting farmers' decisions on utilization of rice straw compost in Northeastern Thailand. J Agric Rural Dev Trop Subtrop 114(1):21–27. https://www.jarts.info/index.php/jarts/article/view/2013030542579/0. Accessed 01.02.2022
Surendran U, Raja P, Jayakumar M, Subramoniam R (2021) Use of efficient water saving techniques for production of rice in India under climate change scenario: a critical review. J Clean Prod 309:127272. https://doi.org/10.1016/j.jclepro.2021.127272
Suwanmaneepong S, Kerdsriserm C, Iyapunya K, Wongtragoon U (2020) Farmers adoption of organic rice production in Chachoengsao province, Thailand. J Agric Ext 24(2). https://doi.org/10.4314/jae.v24i2.8
Terano R, Mohamed Z, Shamsudin MN, Latif IA (2015) Factors influencing intention to adopt sustainable agriculture practices among paddy farmers in kada. Malaysia. Asian J Agric Res 9(5):268–275. https://doi.org/10.3923/ajar.2015.268.275
Tho LCB, Dung LC, Umetsu C (2021) "One must do, five reductions" technical practice and the economic performance of rice smallholders in the Vietnamese Mekong delta. Sustain Prod Consum 28:1040–1049. https://doi.org/10.1016/j.spc.2021.07.018
Tien DN, Hoang HG, Sen LTH (2022) Understanding farmers' behavior regarding organic rice production in Vietnam. Org Agric 12:63–73. https://doi.org/10.1007/s13165-021-00380-0
Tran-Nam Q, Tiet T (2022) The role of peer influence and social norms in organic farming adoption: accounting for farmers' heterogeneity. J Environ Manage 320:1115909. https://doi.org/10.1016/j.jenvman.2022.115909
Tran NLD, Rañola RF Jr, Sander BO, Reiner W, Nguyen DT, Nong NKN (2019) Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. Int J Clim Change Strateg Manag 12(2):238–256. https://doi.org/10.1108/IJCCSM-01-2019-0003
Tu VH, Can ND, Takahashi Y, Kopp SW, Yabe M, Yildiz F (Reviewing Ed) (2018) Modelling the factors affecting the adoption of eco-friendly rice production in the Vietnamese Mekong Delta. Cogent Food Agric 4(1). https://doi.org/10.1080/23311932.2018.1432538
Van Aalst MA, Koomen E, Tran DD, Hoang HM, Nguyen HQ, de Groot HLF (2023) The economic sustainability of rice farming and its influence on farmer decision-making in the upper Mekong delta. Vietnam. Agric Water Manag 276:108018. https://doi.org/10.1016/j.agwat.2022.108018
Widadie F, Agustono, (2015) Comparison of integrated crop-livestock and non-integrated farming systems for financial feasibility, technical efficiency and adoption. J Int Soc Southeast Asian Agric Sci 21(1):31–45
Widarni NAA, Kusumasturti TA, Putra RS (2020) A study on farmers' choice in integrating paddy and cattle farming as farm management practices. J Indones Trop Anim Agric 45(4):356–364. https://doi.org/10.14710/jitaa.45.4.356-364
Wassmann R, Lantin RS, Neue HU, Buendia LV, Corton TM, Lu Y (2000) Characterization of methane emissions from rice fields in Asia. III. Mitigation options and future research needs. Nutr Cycl Agroecosystems 58(1):23–36. https://doi.org/10.1023/A:1009874014903
Wehmeyer H, Malabayabas A, San SS, Thu AM, Tun MS, Thant AA, Connor M (2022) Rural development and transformation of the rice sector in Myanmar: introduction of best management practices for sustainable rice agriculture. Outlook Agric 51(2):223–237. https://doi.org/10.1177/00307270221086008
Yagi K, Sriphirom P, Cha-un N, Fusuwankaya K, Chidthaisong A, Damen B, Towprayoon S (2020) Potential and promisingness of technical options for mitigating greenhouse gas emissions from rice cultivation in southeast Asian countries. Soil Sci Plant Nutri 66(1):37–49. https://doi.org/10.1080/00380768.2019.1683890
Yanakittkul P, Aungvaravong C (2020) A model of farmers intentions towards organic farming: a case study on rice farming in Thailand. Heliyon 6(1). https://doi.org/10.1016/j.heliyon.2019.e03039
Yuan S, Stuart AM, Laborte AG et al (2022) Southeast Asia must narrow down the yield gap to continue to be a major rice bowl. Nat Food 3:217–226. https://doi.org/10.1038/s43016-022-00477-z
Zaman NBK, Ali J, Othman Z (2017) Sustainable paddy cultivation management: system of rice intensification (SRI) for higher production. Int J of Sup Chain Mgt 6(2):235–242
Zhang Z, Macedo I, Linquist BA, Sander BO, Pittelkow CM (2024) Oppportunities for mitigating net system greenhouse gas emissions in Southeast Asian rice production: a systematic review. Agri Ecosyst Environ 361:108812. https://doi.org/10.1016/j.agee.2023.108812