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Case Studies on Reducing Crop Burning in ASEAN Member States

Edited by

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Case Studies on Reducing Crop Burning in ASEAN Member States

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List of Abbreviations

ADB	Asian Development Bank
AI	artificial intelligence
AMS	ASEAN Member States
ASEAN	The Association of Southeast Asian Nations
CCAC Pollutants	Climate and Clean Air Coalition to Reduce Short-Lived Climate
CPO	Crude Palm Oil
CSA	Climate-Smart Agriculture
ERIA	Economic Research Institute for ASEAN and East Asia
EU	European Union
FAO	Food and Agriculture Organisation
GAP	Good Agricultural Practices
IRRI	International Rice Research Institute
Lao PDR	Lao People's Democratic Republic
NGO	non-governmental organisation
Polri	National Police of Indonesia
RSPO	Roundtable on Sustainable Palm Oil

Executive Summary

Agriculture produces large quantities of crops essential for food security, but it also generates substantial amounts of crop residues, including straw, stalks, husks, and leaves. Managing these residues remains a significant challenge across many agricultural regions. While residues can be reused through composting, biochar production, soil incorporation, animal feed, and other productive applications, open-field burning remains common because it is fast, inexpensive, and requires little additional labour or equipment. However, crop burning imposes considerable environmental, health, and climate costs. It releases particulate matter ($PM_{2.5}$), greenhouse gases, and black carbon, contributing to air pollution, transboundary haze, public health risks, and climate change.

Globally, an estimated 33% of crop residues are used as livestock feed, 44% are retained in fields, and around 6% are openly burned, although the share may be significantly higher in countries where burning is widespread and underreported. Because approximately half of all crop residues contain valuable nutrients, retaining or recycling them can improve soil fertility, enhance moisture retention, strengthen soil structure, and reduce erosion. Nevertheless, farmers often continue to burn residues because of labour shortages, limited access to alternative technologies, inadequate market opportunities, and economic pressures. This creates a persistent tension between short-term practicality and long-term sustainability.

Recognising the scale of the challenge, governments and international organisations have increasingly promoted policies to reduce open burning and encourage sustainable residue management. In Southeast Asia, ASEAN Member States adopted the *ASEAN Guidelines on the Reduction of Crop Burning* in 2024, establishing a regional framework to support farmer-friendly policies, technology adoption, capacity building, and knowledge sharing. Earlier initiatives supported by organisations such as the Climate and Clean Air Coalition (CCAC), the Food and Agriculture Organization of the United Nations (FAO), development banks, and other partners have also advanced climate-smart agriculture, biomass utilisation, and low-emission farming practices throughout the region.

International experience demonstrates the importance of creating economic value from agricultural residues. The European Union, through the European Green Deal and Circular Economy Action Plan, promotes the conversion of residues into biogas, biochar, advanced biofuels, bioplastics, and construction materials, while simultaneously strengthening enforcement against illegal burning. Similarly, the World Bank, Asian Development Bank (ADB), and FAO have supported programmes

that combine technology transfer, monitoring systems, capacity building, and economic incentives to reduce open burning.

Economic considerations remain central to farmers' decisions. Open burning often persists because it is the least costly disposal option. Alternatives such as mechanical removal, soil incorporation, composting, and biomass collection typically require additional labour, specialised equipment, processing facilities, or transportation infrastructure. These barriers are particularly significant for smallholder farmers, who dominate agricultural production across much of ASEAN and often face constraints in capital, technology access, and market participation.

Consequently, economic incentives and policy instruments play a critical role in changing behaviour. As demonstrated by the analytical framework presented in this report, farmers' residue-management decisions are largely driven by relative profitability. When burning is effectively cost-free while alternative practices entail additional costs, farmers are likely to continue burning. Governments can alter these incentives through subsidies, cost-sharing schemes, penalties, market-development initiatives, and support for residue-based industries. The analysis further suggests that the availability of multiple residue-utilisation markets significantly increases the economic attractiveness of alternative practices by transforming crop residues from waste into tradable resources.

Technological solutions can support this transition. Broadly, technologies to reduce crop burning fall into three categories: (i) farming and agronomic technologies, (ii) residue utilisation technologies, and (iii) monitoring and management systems.

Farming and agronomic technologies seek to reduce or eliminate burning by improving residue management practices in the field. Common barriers include high upfront costs, limited awareness, insufficient technical support, and reluctance to adopt unfamiliar methods. These challenges can be addressed through machinery-sharing schemes, rental programmes, co-operative ownership models, demonstration projects, targeted subsidies, and locally adapted technologies.

Residue utilisation technologies convert agricultural waste into valuable products, creating new economic opportunities while reducing environmental impacts. Applications include bioenergy production, biochar, compost, animal feed, and industrial materials. Although these technologies can generate significant value, they often require reliable feedstock supply chains, processing infrastructure, logistics systems, and stable market demand. Public–private partnerships and supportive policy frameworks are therefore essential to facilitate investment and scale-up.

Monitoring and management technologies enable governments to enforce regulations, detect burning activities, and support data-driven decision-making. These technologies include satellite monitoring, remote sensing, early-warning systems, and digital reporting platforms. Their effectiveness depends on strong institutional capacity, legal frameworks, data-sharing arrangements, and integration with enforcement mechanisms.

Reducing crop burning is a complex challenge that requires balancing farmers' economic realities with environmental and public-health objectives. No single intervention is sufficient. The most effective approaches combine economic incentives, accessible technologies, strong policy frameworks, market development, capacity building, and context-specific solutions tailored to local agricultural conditions. The adoption of the *ASEAN Guidelines on the Reduction of Crop Burning* provides an important opportunity for Member States to strengthen regional co-operation, share good practices, and accelerate the transition towards more sustainable agricultural systems.

To support implementation of the Guidelines, this study examines country experiences in reducing crop burning across four major agricultural sectors: oil palm in Indonesia, cassava in the Lao People's Democratic Republic, rice in Thailand, and sugarcane in Viet Nam. Drawing on literature reviews and interviews with farmers and stakeholders, the study finds that economic constraints remain the principal barrier to the adoption of alternative practices and technologies. Effective implementation will therefore require financial support mechanisms, investment in appropriate technologies and infrastructure, capacity-building programmes, stronger policy support, and the dissemination of successful practices, including those developed through public–private partnerships. These measures will be essential to achieving sustained reductions in crop burning across ASEAN.

Chapter 1

Reducing Crop Residue Burning in ASEAN: Current Status and Policy Recommendations

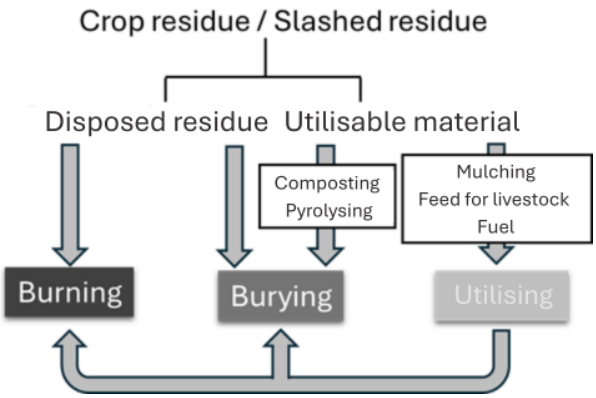
Kentaro Yamada and Siti Mustaqimatud Diyanah

1.1. Background

1.1.1. Management of Crop Residue and Slashed Residue

Throughout the agricultural process, from developing farmland to harvest, some materials that are edible or useful for humans are recognised as crops, while others are residues. The residues are generated mainly by clearing land for farmland, and by cultivation and harvest. The residues are disposed of or partially utilised as biomass, and most are degraded into gases by burning, digestion by organisms (including livestock), and natural weathering. In contrast, buried compost and pyrolysed biochar is isolated from the surface and preserved in the soil, leading to carbon sequestration underground. (Figure 1.1).

Figure 1.1 Outline of Residue Management



Source: Authors' analysis.

Much of the residue is burned to clear the surface of the farmland as this requires the lowest labour and cost. However, residues can also be utilised for biomaterial such as mulching, feed for livestock, fuel, compost, and biochar although that involves higher costs. According to recent global estimates, 33% of crop residue is used for livestock feed and bedding, 44% is left on field, and 6% is burned (Smerald, Rahimi, and Scheer, 2023). Thus, increasing other usage for residues, rather than burning them or leaving them on the fields can help to reduce carbon emissions.

1.1.2. Reducing Burning of Residues

Amongst the residue management processes, burning is expected to decrease because it emits black carbon and greenhouse gases into the atmosphere, affecting other social sectors such as global warming, public health, and worsening visibility. Furthermore, emissions can travel to other areas including neighbouring countries through the atmosphere. However, burning is widely practised because of its convenience and because possible solutions to decrease the amount of burning require regional and multisectoral action. Furthermore, residues from crops and cleared farmland are an integral part of the farming process, and are influenced by a range of factors such as to the variety of crops, farming style, natural conditions, and the circumstances in each country.

As a recent regional initiative, the *ASEAN Guidelines on the Reduction of Crop Burning* was published in 2024 (ASEAN, 2024b). It sets out a framework and roadmap to reduce burning from crop residues and cleared vegetation, and can be used in future guidelines and manuals. However, to implement these guidelines, more specific case studies need to be widely shared. In this report, the authors provide detailed information based on literature and questionnaire surveys for four cases studies: oil palm in Indonesia (Chapter 3); cassava in the Lao People's Democratic Republic (Lao PDR) (Chapter 4); rice in Thailand (Chapter 5); and sugarcane in Viet Nam (Chapter 6).

1.2. Schemes to Promote a Reduction in Residue Burning

To promote a reduction in residue burning, encourage burying residues, and increase the use of residues as biomass, new activities to alter or customise conventional farming practices are required. The ways promoted should be tailored to fit each culture and environment to ensure the initiatives continue sustainably. Current issues and potential solutions are summarised in terms of policies and initiatives, finance and economy, and technology.

1.2.1. Policies and Initiatives

Crop residue burning has caused environmental and social issues worldwide, and many international and domestic policies and initiatives have been implemented.

The Association of Southeast Asian Nations (ASEAN) Environment Ministers adopted a zero-burning policy in 1999, and subsequent guidelines to promote controlled burning processes including the reduction in crop residue burning were published (ASEAN, 2003; 2004). In the agricultural sector, related initiatives such as for biomass utilisation for bioenergy (ASEAN, 2019) and climate-smart agriculture (ASEAN, 2015; 2017; 2022a) have been published. Recent initiatives and related research for promoting sustainable agriculture food systems indicate the

importance of crop residue management (ASEAN, 2022b; 2024a; Kozono, Yamada, and Diyanah, 2023; Kozono, Yamada, and Anbumozhi, 2025). The reduction of burning has gained attention in the context of the reduction of greenhouse gas emissions, such as the ASEAN Strategy on Carbon Neutrality (ASEAN, 2023) and the launch of Asia Zero Emission Center in the Economic Research Institute for ASEAN and East Asia (ERIA) (ERIA, 2024). Thus, the *ASEAN Guidelines on the Reduction of Crop Burning* (ASEAN, 2024b) was based on many prior initiatives across multiple contexts.

The Common Agriculture Policy in the European Union (EU) has also addressed residue burning. EU member states have largely banned stubble burning as part of maintaining soil organic matter under the Good Agriculture and Environment Conditions, which encourages farmers to comply with these standards to receive aid (Searle and Bitnere, 2017). The New Common Agricultural Policy was introduced in 2023 and continues to ban burning as one of the Good Agriculture and Environment Conditions (European Commission, 2023).

Additionally, the United Nations Economic Commission for Europe published a guidance document on the reduction of emissions from agricultural residue burning (UNECE, 2022). The document recommends sustainable, practical measures to reduce residue burning and the implementation of relevant policies in the EU and other United Nations Economic Commission for Europe member countries.

Other organisations of the United Nations have also implemented projects to reduce crop burning. The Food and Agriculture Organization supported a reduction in crop burning in India by implementing the Bioenergy and Food Security approach (FAO, 2014; 2020). This approach has been developed through specific case studies (e.g. FAO, 2018), which assess ways to install technologies to utilise residues based on economic considerations.

Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC), launched by the United Nations Environment Programme in 2012, promoted agricultural initiatives to facilitate the adoption of alternatives to open burning (CCAC, 2019; UNEP, 2021). These projects and subsequent activities aim to implement practices to reduce crop burning in some areas and are initiatives to mitigate climate change (CCAC, 2019).

Recent programmes by organisations such as the World Bank and the Asian Development Bank have promoted crop residue management, including efforts to reduce crop burning in China (World Bank, 2016; UNFCCC, 2023), India (World Bank, 2023; ADB, 2023), and Pakistan (Mishra et al., 2024). These theoretical and practical projects, being funded by banks and with collaboration from the private sector, have

also effectively strengthened national initiatives in each country.

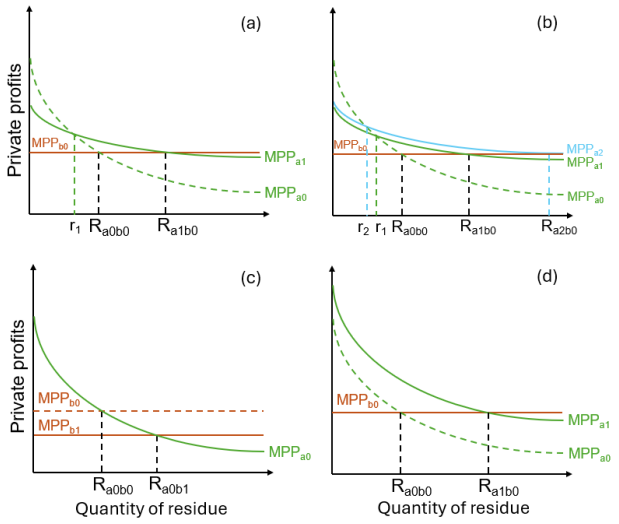
1.2.2. Economical and Financial Solutions

Burning is the easiest way for farmers to eliminate residues from farmland, meaning that alternative methods to eliminate residues require additional cost. Therefore, economically beneficial methods are required to encourage farmers to reduce burning.

Financial incentives and subsidies to implement non-burning measures have been introduced and are likely to be effective in the short term (Shaikh, 2023; Yamada and Anbumozhi, 2025). For example, straw management using machinery without burning has been shown to be more profitable than burning (Shyamusandar et al., 2023). Financial schemes can be applied variably, taking into consideration the local background and timeframe (Yamada and Anbumozhi, 2025), while theoretical market models could support the promotion of non-burning methods by increasing the farmers' benefits.

Considering the farmers' decision-making processes, burning is a low- or zero-cost method, but does not generate profits. Non-burning methods are thought to be more profitable for farmers if the residue has sufficient value in the market. While Krishna and Mkondiwa (2023) proposed a useful economic model to think about the profitability of crop residues, subsidies and penalties have been implemented; thus, farmers make decisions based on economic profitability and other factors. In this report, an updated model is introduced, which explains the four schemes shown in Figure 1.2.

Figure 1.2. Profit Schemes from Single Residue



R_{a0b0}, R_{a1b0}, R_{a2b0}, R_{a0b1}, r_1, and r_2 are intersections of MPP_{a0} and MPP_{b0}, MPP_{a1} and MPP_{b0}, MPP_{a2} and MPP_{b0}, MPP_{a0} and MPP_{b1}, MPP_{a0} and MPP_{a1}, and MPP_{a0} and MPP_{a2}.
Source: Authors' analysis.

1.2.2.1. Alternative Utilisation Pathways of a Single Residue

In Figure 1.2, MPP_{a0}, MPP_{a1}, and MPP_{a2} indicate marginal private profits from selling residues. MPP_{b0} and MPP_{b1} indicate marginal private profits from burning. For simplicity, MPP_{b0} is assumed to be constantly zero in this model. The quantity of residue is expressed as the variable R. Functions of MPP_{a0}, MPP_{a1}, and MPP_{a2} are defined as $F_{a0}(R)$, $F_{a1}(R)$, and $F_{a2}(R)$ each. R_{a0b0}, R_{a1b0}, R_{a2b0}, R_{a0b1}, r_1, and r_2 are intersections of MPP_{a0} and MPP_{b0}, MPP_{a1} and MPP_{b0}, MPP_{a2} and MPP_{b0}, MPP_{a0} and MPP_{b1}, MPP_{a0} and MPP_{a1}, and MPP_{a0} and MPP_{a2}. If there is single residue market along with MPP_{a0}, MPP_{a1}, or MPP_{a2}, the maxima of total private profit, considering the farmers' decisions, are defined as P_{a0}, P_{a1}, and P_{a2}, and are calculated as equations (1.1), (1,2), and (1,3). It is noted that $MPP_{a0}>MPP_{b0}$ is indicated for $0<R<R_0$, i.e. selling residue is more profitable than burning, while excess R than R_{a0b0} is burned with no profit since $MPP_{a0}<MPP_{b0}$ is indicated for $R_{a0b0}<R$.

$$P_{a0} = \int_0^{R_{a0b0}} F_{a0}(R)dR \quad (1.1)$$

$$P_{a1} = \int_0^{R_{a1b0}} F_{a1}(R)dR \quad (1.2)$$

$$P_{a2} = \int_0^{R_{a2b0}} F_{a1}(R)dR \quad (1.3)$$

MPP_{a1} represents another case of residue utilisation. It is notable that $R_{a0b0}<R_{a1b0}$ is required because the amount of burning should be decreased. It can be considered with Figure 1.2(a) that if farmers should choose one market from two markets comprising MPP_{a0} and MPP_{a1}, they would consider whether P_{a0} or P_{a1} is more profitable from an economic viewpoint whereas $R_{a0b0}<R_{a1b0}$ is required. That indicates that $P_{a0}<P_{a1}$ is necessary as well.

On the contrary, as shown in Figure 1.2(b), a sufficient factor to shift MPP_{a1} to MPP_{a2} is required to satisfy $P_{a0}<P_{a2}$ while $R_{a1b0}<R_{a1b0}<R_{a2b0}$ is obvious. For instance, fodder corresponds to MPP_{a0} and mulching corresponds to MPP_{a1} (Krishna and Mkondiwa, 2023). Thus, if the mulching market is sufficiently efficient, residues will not be burned even if crop residue are too abundant for the fodder. Carbon credit would be categorised in this case and show MPP_{a1} because the market is sufficiently large

so MPP_{a1} would show an almost stable or slightly decreasing trend.

The scheme of Figure 1.2(c) always satisfies $R_{a0b0}<R_{a1b0}$ and $P_{a0}<P_{a1}$. This is found not only in the case of differences in the residue values but also when subsidies are added on the value (Krishna and Mkondiwa, 2023). For instance, incentives for practitioners of alternative ways fall under this scheme. Subsidies are indirectly applicable because they decrease the initial cost of the instalment of alternative ways and are reflected in increased profit. Tax breaks lead to a decrease in the expenditure for practitioners, thus they raise profits. In addition to these schemes, installing machinery is effective to decrease costs. Subsidies, tax breaks, and loans for the installation of machinery would more effectively decrease costs. Such alternative ways which need higher cost are analysed in terms of technical and economic feasibility (Saleem, 2022).

Figure 1.2(d) shows that MPP_{b1} is lower than MPP_{b0}. In this model, MPP_{b0} is set as constantly zero, thus MPP_{b1} indicates a minus value for all R. That is interpreted as the case of a penalty for burning. If the penalty is imposed on farmers, they would sell the residue if the cost exceeded the benefit, provided the deficit is smaller than the penalty.

1.2.2.2. Alternative Utilisation Pathways of Multiple Residues

If multiple markets are available for farmers, they would use them to maximise their profits. If MPP_{a0} and MPP_{a1} are available in Figure 1.2(a), and MPP_{a0} and MPP_{a2} are available in Figure 1.2(b), the maximised total profits are defined as P_{a0a1} and P_{a0a2} each and calculated as equations (2.1) and (2.2). (Note: MPP_{a1} is always altered by MPP_{a2} in the case of Figure 1.2(a))

$$P_{a0a1} = \int_0^{r_1} F_{a0}(R)dR + \int_{r_1}^{R_{a1b0}} F_{a1}(R)dR \quad (2.1)$$

$$P_{a0a2} = \int_0^{r_2} F_{a0}(R)dR + \int_{r_2}^{R_{a2b0}} F_{a2}(R)dR \quad (2.2)$$

In this model, $P_{a0a1}>P_{a0}$ and $P_{a0a1}>P_{a1}$ for equation (2.1), and $P_{a0a2}>P_{a0a1}$ and $R_{a2b0}>R_{a1b0}$ for equation (2.2) always hold. The point is that multiple markets make more profits than single market.

The summary of the necessary conditions for each case are indicated in Table 1.1. It is interpreted that the penalty and subsidies are effective if the situation continues, and the residue market is conditionally effective and is adjustable to satisfy the requirements. Figure 1.2(a) and (b) represent the initial stage of the development of sustainable crop residue conducted by the government and institutions, and Figure 1.2 (c) and (d) are under further development and the government intervention, which corresponds to stage 2 and stage 3 respectively, proposed by Krishna and Mkondiwa (2023). Combined initiatives such as subsidies for residue markets and penalties for burning are more effective than individual initiatives. However, it should be considered that the intervention by the government would be limited, and subsidies and penalties might not be implemented if the residue market is sufficiently large and competitive.

Table 1.1. Summary of the Requirements for Each Scheme in Figure 1.2

	Change	Requirement for burning reduction	Requirement for profit increase
(a) and (b)	Slope of MPP_{a0}	$R_{a0b0}<R_{a1b0}$	$P_{a0}<P_{a1}$ (single) None (multiple)
(b)	MPP_{b0} with minus value	None	None
(c)	Shift MPP curve upper	None	None

Source: Authors' analysis.

1.2.3. Technologies for Reducing Burning of Crop Residues

Technologies to reduce crop burning have been implemented in many areas and offer three key benefits: reducing crop burning through improved farming technology, promoting residue utilisation through energy technologies, and preventing fires through monitoring and managment technologies. While these technologies have demonstrated effectiveness, challenges remain in encouraging farmers to move away from conventional practices. Table 1.2 summarises the three categories of technologies, together with the associated challenges and potential solution in terms of cost, technical requirements, infrastructure, dissemination, and policy and regulatory support. A key constraint is that alternative technologies are often not readily accepted by farmers, which can limit their adoption and effectiveness.

Table 1.2. Summary of the Three Types of Technologies to Reduce Crop Burning

Type	Alternative technologies	Cost		Technique		Infrastructure		Dissemination		Policy and regulation	
		Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions
Farming	No-till farming	Increased costs for machinery and herbicides	Subsidy to buy machinery; Rental services	Microbial infestation; Nutrient immobilisation	Appropriate cultivation management (e.g. nitrogen fertiliser)	Lack of sufficient machinery in a region	Developing regional service centres for rental services	Resistance to new technologies; Difficult to realise the effect of new technologies	Demonstration farm; Sharing good practice	Insufficient support for enforcing policies and regulations	Support to promote the policies (e.g. subsidies; compensation)
	Machinery	Expensive for farmers	Subsidy to buy machinery	Residues on the surface might cause malfunction; Large tractor is required for a dedicated seed drill	Improved machinery and proper operation	Insufficient number of machines	Deploying machinery in communal facilities; Promoting rental businesses	Doubts about whether the benefits are more than the instalment cost; Lack of skill to operate machinery	Introduction of good practice and demonstrations in the region	Establishing suitable system to support the instalment of machinery	Incentives for machinery manufacturer; Simplifying the subsidy system
	Compost and biodegradation	Lavor and time-consuming; Difficulty of business	Evaluating the effectiveness of compost	Techniques are required to promoting biodegradat	Chopping residues to smaller fragments;	Difficulty for farmers to prepare sufficient place and facility	Establishing communal composting facilities	Compost is considered labour-intensive	Promoting the recognition that compost is more	Lack of policies to promote composting in	Promoting circular agriculture (e.g. subsidy to establish

				ion of residues	Co-ordination of C/N ration				effective in the longer term	agriculture	compost facilities)
	Biomass utilisation	Cost for collection, transport, and production	Matching the demand side and ensuring economies of scale	Necessity of appropriate treatment process and production processes	Development of pretreatment and production technology	Ensuring the infrastructures of raw materials procurement; Transportation, and storage	Investment and co-operation by public and private sectors	Farmers thought that selling residues is a hassle	Presenting the economic benefits for farmers	High initial investment and business risk for private sector	Demand creation and price support

(continued)

Type	Alternative technologies	Cost		Technique		Infrastructure		Dissemination		Policy and regulation	
		Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions
Energy	Biofuel and biogas	Cost for the construction and maintenance of a plant	Optimisation of scale, adding value to the product	Residues with high lignin content are difficult to be fermented	Appropriate pretreatment before fermentation	Lack of facilities for utilising, storage, and transportation of biofuel	Establish large and small plants of biofuel	Unfamiliar to operate plants adequately	Simple and reliable plants	Appropriate policy inducement	Including utilisation of biofuel generated from crop residues in the renewable energy policy
	Biochar	Installation cost of the	Dissemination of low-cost	Producing biochar	Providing controllable	Insufficient number of equipment and	Combination of small and	Lack of awareness for biochar	Demonstration of the	Lack of legal	Scheme to promote

		equipment for pyrolysis	equipment	with stable quality; Reducing pollutant emission	equipment and process	collecting system	large equipment	amongst farmers	effectiveness of biochar	position of biochar	using biochar; Carbon crediting
	Pellet fuel and briquette	Initial and running cost for machinery, unstable price	Securing demands for pellets	Generating slag in the process to make pellets from agricultural residues	Blending wood chip and bagasse with straw	Necessity of facilities for supplying raw materials	Combination of mini-pellet mill and large plant	Unstable demand and supply of pellets	Demonstrating economic benefits for farmers; Demonstrating less modification of boiler is required, ash is utilised	Pellets are not included energy policy; Necessity of policy inducement for creating market	Promoting pellets in energy policy

(continued)

Type	Alternative technologies	Cost		Technique		Infrastructure		Dissemination		Policy and regulation	
		Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions	Issues	Solutions
Monitoring and management	Remote sensing	Limited availability of high-resolution images and resources	Utilising free data and increase resource inputs to analysis	Difficult to detect small and short-time burn; Effect of cloud, false positive	Combination of multiple data resources	Constructing monitoring system and transmission facilities	Setting up a monitoring centre and specialised team	Less understood the effectiveness and necessity	Training and awareness-raising to using remote	Establishing legal action based on the result of monitoring	Having a clause to specify the use of the data of remote

		to analyse them							sensing data		sensing as evidence
	Drone	Cost for the equipment and labour cost for operator	Outsourcing to private company during the season	Limited flight time; Difficult to operate under windy condition	Utilising high-speck drones	Necessity of facilities for drone operation and transmission	Utilising buildings in the village and mobile communication	Doubt to the effectiveness	Conducting a pilot test	Necessity of compliance with aviation laws and regulation of data management	Applying the regulations of drone use for agricultural purposes and monitoring purposes
	AI	Initial cost for experts and computational resources to develop the model	Utilising existing platforms and open-source to reduce development cost	Lack of reliable database; Difficulty of data interpretation	Collecting necessary data	Necessity of calculation resources, data storage, and transmission equipment	Utilising cloud services	Low expectation of and doubts about AI	Demonstrating the results expected by AI	Lack of appropriate laws and guidelines	Gradual introduction of the rules to shift to the new model when AI model updated

AI = artificial intelligence.

Source: Authors' analysis.

1.2.3.1. Farming Technologies

1.2.3.1.1. No-Till Farming

No-till farming, where crop residues are left on the soil after harvesting and the next crop is sown without tilling, is a typical method of disposing of crop residues without burning them. The residue covers the ground surface and contributes to soil moisture retention and organic matter accumulation, which can improve yields and the soil environment in the long term.

No-till farming faces several significant barriers to widespread adoption, each requiring targeted solutions. The cost of specialised equipment like no-till seeders such as the Happy Seeder (Listman, 2020) presents a major financial obstacle, particularly for small-scale farmers, while the initial need for increased herbicide use adds to operational expenses. As a potential solution, governments can address these financial challenges through subsidy programmes and by promoting shared-equipment models. In India, under the project Promoting Regenerative and No-Burn Agriculture in India, service providers rent out Happy Seeders (The Nature Conservancy, 2021). Additionally, as a recent case shows, the state government of Madhya Pradesh in India provides subsides for individual farmers to purchase Happy Seeders (Government of Madhya Pradesh, 2025). Shyamsundar et al. (2019) show that, in some cases, farmers with Happy Seeders earned 15% more profit (up to $164[1] more per hectare) than those using conventional burning. Demonstrating such benefit data can increase economic incentives. This leads to the development of machinery rental services which can effectively support the implementation of the machinery (Singh, 2017). However, from the infrastructure viewpoint, it is important to ensure there is sufficient machinery during the appropriate season.

Technical challenges primarily involve managing crop residues, which may temporarily create negative effects that can be transmitted to the next crop such as the immobilisation of soil nitrogen (USDA, 2016), and microbial infestation (Bhuvaneshwari et al., 2019). Farmers can overcome these issues through proper cultivation management with, for instance, supplemental nitrogen application during transition years.

Another barrier to the adoption of no-till farming is resistance rooted in traditional farming practices. Farmers may also doubt whether no-till farming is more effective than conventional farming. Demonstration farms and peer-to-peer knowledge transfer would be particularly effective to build farmers' confidence.

Effective policy frameworks to promote no-till farming should be required as well,

[1] In this report, $ means United States dollar.

and combine support mechanisms with appropriate regulations, including equipment subsidies, carbon farming incentives, and graduated enforcement of residue burning bans.

Successful no-till adoption requires integrated solutions that address financial, technical, and social dimensions simultaneously. The key lies in developing context-specific implementations of these fundamental approaches to overcome local adoption barriers.

1.2.3.1.2. Machinery for Alternative Residue Management

To prevent crop residue burning, the introduction of specialised machinery is essential. Key equipment includes chopping and spreading attachments, shredders that mix residues into the soil, balers that collect straw, and no-till seeders. These machines help manage residues efficiently.

As described in subchapter 1.2.3.1.1, cost is a major barrier to purchasing expensive machinery; subsidies and sharing machinery are the ways to support its installation. However, to promote machinery enhancements, technical issues – including machines clogging due to wet or long stalks, and limited compatibility with smaller tractors – should be addressed as well. Solutions include to improve equipment design, with lighter seeders and anti-clogging features, and to provide operator training for optimal machine use (Kaur et al., 2023).

To improve machinery utilisation, the shortage of machines and operators during peak seasons and a lack of repair facilities needs to be addressed. As indicated in subchapter 1.2.3.1.1, utilising rental services and communal facilities in the region would be effective. It is also important to note that barriers to dissemination can stem from farmers' unfamiliarity with new technologies and doubts about their value. Demonstrations, peer testimonials, and labour-saving services reduce resistance, while training programmes, particularly for young farmers, build confidence (Kaur et al., 2023).

Additionally, policy and regulatory support is often hampered by complicated subsidy procedures and limited eligible models. Streamlining processes, expanding subsidy access, and mandating equipment standards can promote adoption. These multisectoral activities support the installation and use of machinery.

1.2.3.1.3. Compost and Biodegradation

Composting crop residues offers a sustainable alternative to burning, enriching the soil and reducing dependency on chemical fertilisers and pesticides. Particularly

effective for high-carbon materials like rice straw, composting improves soil health, enhances moisture retention, and promotes long-term agricultural productivity (e.g. Bhuvaneshwari, Hettiarachchi, and Meegoda, 2019).

While it is effective, composting is more labour-intensive and time-consuming than burning, with unclear immediate economic benefits, especially when sold commercially. This can also act as a dissemination hurdle. However, when used on-farm, it reduces input costs and enhances yields over time, as was seen in the Rashtriya Krishi Vikas Yojna project in India which trained farmers and demonstrated profitability through compost sales and fertiliser savings (Singh and Prabha, 2017).

Effective composting requires proper biodegradation. It depends on moderate carbon-to-nitrogen ratios, as well as managing moisture and aeration (Bhuvaneshwari, Hettiarachchi, and Meegoda, 2019). For instance, reports suggest that microbial decomposers can be effective to improve soil health (e.g. Chawla, 2022; Lamba and Gill, 2024).

Infrastructure challenges stem from the need for space, water, and machinery. Regional composting facilities offer a scalable solution by pooling residues and equipment. In a recent case in India, a large-scale composting unit has been developed which is part of a project to improve product distribution (Gutiérrez and Robles, 2023). Policy support remains limited, but is crucial. Clearer integration of composting into agricultural and environmental policy, coupled with subsidies and tax incentives, including for developing infrastructure, can create an enabling environment.

1.2.3.1.4. Biomass Utilisation

Biomass utilisation of crop residues offers a sustainable alternative to burning by converting them into valuable products such as animal feed, mushroom substrates, bioplastics, and construction materials. This not only adds economic value but also reduces environmental harm.

Economically, residues like straw are bulky and low value, making transportation and processing costly (Lohan et al., 2018). Profitability can be improved through economies of scale, such as bulk purchasing by thermal power plants (Bhuvaneshwari, Hettiarachchi, and Meegoda, 2019). Additional value is created by turning residues into eco-friendly products, like biodegradable packaging made from materials such as straw (Sain, 2020). Additionally, infrastructure is critical for scaling up and improving profitability. Large quantities of residue must be collected quickly postharvest and stored year-round. This requires machinery, trucks, and secure storage facilities.

Technical consideration is also crucial because residue transformation requires proper pretreatment. For instance, rice straw's high silica content complicates pulping, so it requires an additional chemical treatment during the pulping process (Nayeem et al., 2023).

Dissemination of residue utilisation hinges on convincing farmers of the benefits. Key strategies to achieve this include fair pricing, hassle-free collection, and compensating soil nutrient loss by removing ash after burning. Policy support is also essential to promote farmers' actions and support the industry's high startup costs.

1.2.3.2. Utilisation of Residues for Materials and Energy

1.2.3.2.1. Biofuel and Biogas

Biofuel and biogas are produced by decomposing organic matters to low-molecular compounds such as ethanol and methane through fermentation, pyrolysis, or other industrial process. Generating them from agricultural residue offers an effective way to reduce burning and utilise unused biomass as well as to promote renewable energy generation.

While biofuel and biogas are effective, building and maintaining plants is expensive (e.g. Jameel et al., 2024). Large plants that produce biogas incur high collection costs, while small, decentralised units struggle with underutilisation. Additionally, a distribution network in a village is also required to make small plants work. Medium-scale plants that process both manure and crop residues are the optimal solution at the village level, allowing year-round operation. That could be supported by the government initiatives. For instance, the Sustainable Alternative Towards Affordable Transportation scheme is a government initiative in India and promotes utilisation of biogas as automotive and industrial fuels (Indian Oil Corporation Limited, 2025).

Technologically, the lignin-rich nature of residues like rice straw limits fermentation efficiency. Pretreatment methods such as crushing, the use of steam, or chemical treatments are essential to break down lignin (e.g. Kumar et al., 2009; Chandra, Takeuchi, and Hasegawa, 2012). Co-digestion with nitrogen-rich materials like manure stabilises the process (Einarsson and Persson, 2017).

Additionally, hurdles to dissemination amongst farmers should be addressed. Biogas and biofuel require initial costs for infrastructure and an additional burden on farmers to collect and store the residues. To decrease such loads and raise awareness of the benefits of utilising residues for biogas and biofuel, it is essential to ensure easier maintenance of plants, stable markets and contracts for residue

collection. Policy initiatives and regulations, such as those under renewable energy policies, are also effective in promoting these activities.

1.2.3.2.2. Biochar

Biochar, a carbon-rich material produced by pyrolysing crop residues under low-oxygen conditions, is gaining attention for its dual role in improving soil quality and mitigating climate change through long-term carbon sequestration.

Producing biochar is costly because specific equipment for pyrolysis is necessary and modern carbonisation equipment is expensive. Solutions include low-cost, field-scale retort kilns and shared the systems, which reduce costs through co-operative use (Kamal, 2023). Additionally, biochar is not only sold as a commodity, but can also produce carbon credits, providing additional income for farmers (e.g. Salma, Fryda, and Djelal, 2024). To promote biochar utilisation, technology for producing consistent, high-quality biochar while minimising harmful emissions is also required, but this is challenging. Improving equipment and establishing optimised combustion methods help reduce smoke and pollution.

From an infrastructure perspective, both decentralised (on-farm units) and centralised (regional plants) models are viable. Decentralised models reduce transport needs, while centralised ones benefit from operational efficiency. Governments can aid infrastructure by subsidising equipment and facilitating deployment strategies. Proper storage (e.g. bagged or siloed) is also essential to maintain biochar quality and minimise health risks. Policy support is crucial to promote the implementation of biochar. Clear legal recognition, quality standards, and inclusion in carbon credit systems can boost adoption. Government-led trials, regulation simplification, and manufacturer certifications can further streamline uptake and encourage both private and public participation in scaling biochar use.

Ways to disseminate information amongst farmers depends on raising their awareness through demonstrations of biochar's benefits, like improved yields and reduced fertiliser use. Simplified handling (e.g. pellets) and commercial sales models can lower adoption barriers, especially early on.

1.2.3.2.3. Pellet Fuel and Briquettes

Pellet and briquette fuel technologies convert crop residues, such as rice straw, into dense, solid fuels that are easier to handle, transport, and store. These pellets can be used in boilers and stoves, offering a renewable alternative to coal. While wood pellets have been well-established, interest is growing in pellets made from agricultural waste (Svensson et al., 2024).

However, cost remains a key barrier due to the high capital and operational expenses of production equipment (Ibitoye et al., 2021). Long-term contracts with power companies, for example, would help mitigate investment risk. Government subsidies, especially for equipment and logistics, also support cost reductions. Value-added products like torrefied pellets can command higher prices and improve profitability while labour costs affect the price (Sarker et al., 2023).

While the challenges and potential solutions for pellet fuel and briquette infrastructure are similar to those of biochar (see subchapter 2.3.2.2), technical challenges include high ash, silica, and water content in agricultural residues, leading to slag formation (Strand et al., 2019) and reduced boiler efficiency (Ibitoye et al., 2021). Solutions include proper treatment such as drying residues (Ibitoye et al., 2021) and adding minerals such as kaolin (Mack et al., 2019).

For wider dissemination, it is necessary to inform farmers that pellets and briquettes can be profitable. Policy initiatives could also promote these activities. For instance, the installation of pellet and briquette systems could be supported by energy policies. Subsidies and tax exemption would be effective as well.

1.2.3.3. Monitoring and Management

1.2.3.3.1. Remote Sensing

Remote sensing has become a powerful tool to monitor and reduce agricultural residue burning across wide areas. Traditionally, tracking small-scale rural fires was difficult, but advancements in satellite technology now enable real-time fire detection.

One major barrier is the cost of real-time and high-resolution imagery and the expertise needed for analysis. However, free satellite data and platforms like Fire Information for Resource Management System provided by NASA can offset costs. Collaborations between governments and research institutions, as seen in Punjab and Haryana, India, have reduced monitoring costs and improved fire control, which contributed to a 38% drop in fires in Punjab and a 25% drops in Haryana within a year (Bhuvaneshwari, Hettiarachchi, and Meegoda, 2019).

Technically, satellites have limitations in resolution, weather interference, and false positives. Combining multiple data sources (e.g. the Fire Information for Resource Management System and other satellites such as Sentinel-2), time-series vegetation analysis (Bahşi et al., 2023), and machine leaning recognition can improve accuracy (Bai et al., 2022). The data should be adequately analysed by central monitoring centres, data communication systems, and Geographic Information System databases. The analysis is used to patrol the area. Using such

collaborative systems, comprising data-obtaining technology and data-utilising infrastructure requires training for officials, and public awareness.

From a policy perspective, laws must allow remote sensing data as legal evidence for enforcement. India uses satellite data for fines and performance tracking (Bhuvaneshwari, Hettiarachchi, and Meegoda, 2019). Policies should balance penalties with incentives, rewarding communities that reduce burning. Embedding remote sensing in regulation ensures sustainable monitoring and enforcement.

1.2.3.3.2. Drones

Drones are increasingly being used in agriculture for various purposes, including pesticide application, field monitoring, and residue incineration management. Drones are particularly effective in detecting small fires and night-time smoke, which may be missed by satellites.

Cost is a challenge, with high-performance drones and thermal cameras being expensive. One solution is to use drones for multiple purposes to reduce costs. In India, the government of Punjab installed drones for multi-purpose uses including monitoring small-scale burning of crop residues (Nibber, 2022). Additionally, drones can be shared across multiple villages or used for a variety of agricultural tasks, increasing cost-effectiveness. Local young people could be hired as drone pilots, which would create employment opportunities and reduce labour costs.

Common technical challenges for using drones, such as limited battery life, difficulty flying in strong winds, and restrictions on night flights should be understood. It is also necessary to install systems for analysing data gathered. Good practice suggests that the solution is drone-utilisation with an internet-connected system (Sharma and Singh, 2023), while subsidies should be the answer to the issues of cost.

Infrastructure for drone operations includes bases for take-off and landing, maintenance facilities, and a communication network for real-time video transmission. Networks with 4G or 5G support this infrastructure, and software platforms help manage multiple drones. Airspace management is easier in rural areas, and regulatory approvals can be obtained for drone operations.

Policies and regulations for drone use are crucial. Clear guidelines are needed for agricultural drone operations, including permits for flights at night and in restricted areas. Privacy and data management issues must also be addressed, and a co-ordinated approach involving regulators and local authorities is essential for widespread drone adoption in agriculture.

1.2.3.3.3. Artificial Intelligence

Artificial intelligence (AI) is increasingly applied to the complex issue of residue burning, as it is helpful for analysing data being used as part of remote sensing to monitor crop residue burning (Bai et al., 2022) and crop residue management (Ferdous et al., 2023).

While AI is convenient, the high initial expense of developing AI systems, including the need for expertise and computational resource, makes them expensive. However, once developed, AI models are cost-effective in the long run as they automate forecasting and analysis. To reduce costs, existing platforms and open-source software like Google Earth Engine can be utilised, and collaboration with research institutes can help cover personnel costs.

Technical challenges revolve around the need for high-quality data. Ensuring accurate predictions requires reliable data sets, such as satellite fire detection and field records. AI models need to be simple for users to interpret, with visualisation tools like colour-coded probability maps for ease of use. Models should also be adaptive, incorporating new data and policies to stay relevant.

Infrastructure for AI requires computational resources, large data storage, and reliable communication networks. Cloud computing services such as Google Cloud and Amazon Web Services offer scalable solutions for data processing and storage. For areas lacking local cloud adoption, centralised data centres could facilitate AI analysis and dissemination of results.

Policy and regulation should clarify the boundaries of responsibility for AI predictions, treating AI as a tool for human decision-making. Ethical guidelines should ensure AI operates without discrimination, and national frameworks for AI use in agriculture and environment should be established, supported by government-backed technical and financial assistance to promote AI adoption.

For new technologies such as remote sensing, drones, and AI, doubts about the installation of the technologies are the common issues that hamper dissemination. Demonstrating their effectiveness with historical data and pilot projects, as well as emphasising human oversight in decision-making, can increase acceptance. Transparency and regular feedback between the systems with new technologies and field staff are key to building trust and co-operation.

1.3. Summary of Case Studies in the ASEAN Region

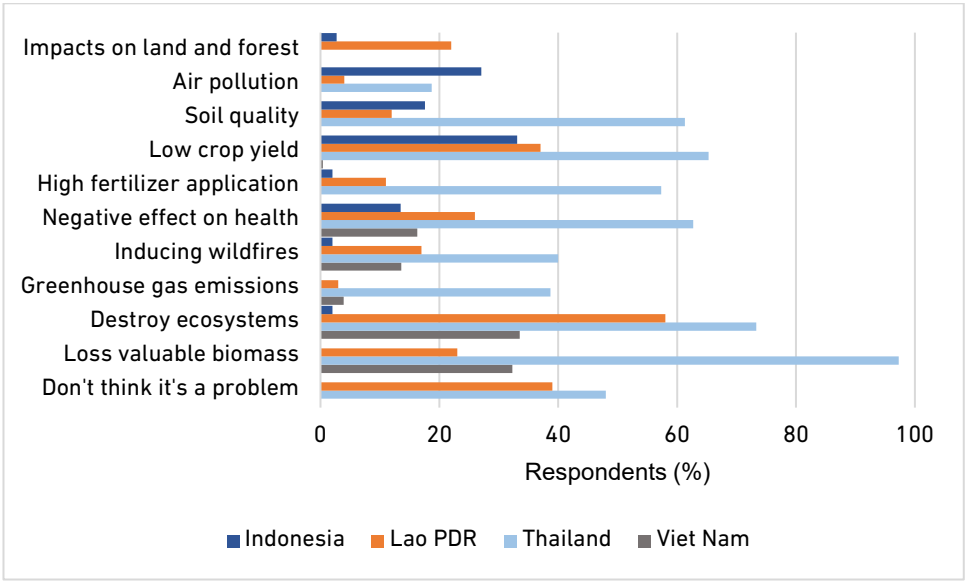
1.3.1. Current Status of Crop-Burning Activities in ASEAN

This study engaged with four ASEAN Member States and identifies crop-burning

activities in different crops. The study in Indonesia focused on crop burning in oil palm plantations, while in Lao PDR, the focus was on crop burning in cassava cultivation. In Thailand crop-burning practices in rice production were considered, while in Viet Nam, a major sugarcane producer, crop-burning practices in sugarcane cultivation were studied.

The study looked at the current status of crop burning in each country. Some countries practice crop burning as a method of land clearing, while others apply it for postharvest residue removal. The majority of respondents indicated that it has negative environmental impacts. From the farmers' point of view, many believe that crop burning is an effective and low-cost method for removing crop residue from the field, while others believe that burning residues can bring quick fertiliser to their soil and destroy pests and diseases for their new crops. Furthermore, open burning serves not only for crop residue management but also for the disposal of weed residues. Figure 1.3. shows that the respondents agreed on the negative impact of crop-burning activities.

Figure 1.3. Problems Created by Crop-Burning Activities in ASEAN Member States



ASEAN = Association of Southeast Asian Nations; Lao PDR = Lao People's Democratic Republic.

Source: Authors.

The study showed respondents' awareness of the environmental impact of crop burning for their farming activities. Each country has a different concern about the environmental impact. Lao PDR, Thailand, and Viet Nam highlighted that crop burning significantly harms ecosystems and causes valuable biomass loss.

Indonesia, Lao PDR, and Thailand also raised concerns about the economic impact of burning, such as low crop yield. However, some of the respondents in Lao PDR and Thailand did not think that crop-burning activities were a problem. Overall, however, these findings highlight the need for better crop residue management without burning.

1.3.2. Applied Technologies for Crop Residue Management

Burning crop residue is often considered the most cost-effective and straightforward method to dispose of crop residue. However, the negative impacts of crop burning are more comprehensive, particularly in terms of its environmental impact. Thus, alternative technologies for reducing crop-burning activities are necessary. The findings of the study show that the adoption of alternative technologies for managing crop residues in farming remains low. Multiple challenges are hindering farmers from applying more sustainable technologies. (Table 1.3)

Table 1.3. Applied Technologies for Crop Residue Management in ASEAN Member States

No.	AMS	Type of crop	Applied technology
1	Indonesia	Oil palm	- Removed from the field for other uses (47.8%) - Others, such as utilise residue as mulch, compost, bioenergy, feedstock for livestock (30.4%) - Rolled with a heavy roller to crush the weeds into the soil surface (21.7%)
2	Lao PDR	Cassava	- Open burning (88.8%) - Utilised technologies such as large tractors to incorporate residues into the soil, leaving them in the field while applying herbicides for weed control (11.2%)
3	Thailand	Rice	Wet season - Chopped and then incorporated into the paddy (52.0%) - Feedstock for livestock (32.0%) - Burned spread in the field (30.7%) and burned in a pile (9.3%) - Sale the straw bales (29.3%) Dry season - Chopped and then incorporated into the paddy (42.5%) - Sale the straw bales (32.5%) - Burned spread in the field (27.5%) and burned in a pile (10%) - Feedstock for livestock (20%)
4	Viet Nam	Sugarcane	- Vegetative mulching (46.0%)

			- Open burning (31.6%) - Using green tops and water shoots as cattle feed (17.1%) - Shredding (5.3%)

AMS = ASEAN Member State; ASEAN = Association of Southeast Asian Nations; Lao PDR = Lao People's Democratic Republic.

Source: Authors' analysis.

In Indonesia, oil palm farmers did not burn the residue from postharvest activities (palm trunks). The handling methods applied to oil palm residue are still manual. Most respondents used manual methods or chainsaws for cutting and shredding palm trunks. Some respondents applied replanting methods. The study identified that a common practice is to use old palm trunks as mulch or compost. Additionally, palm trunks are often converted into bioenergy or processed for use in animal feed production.

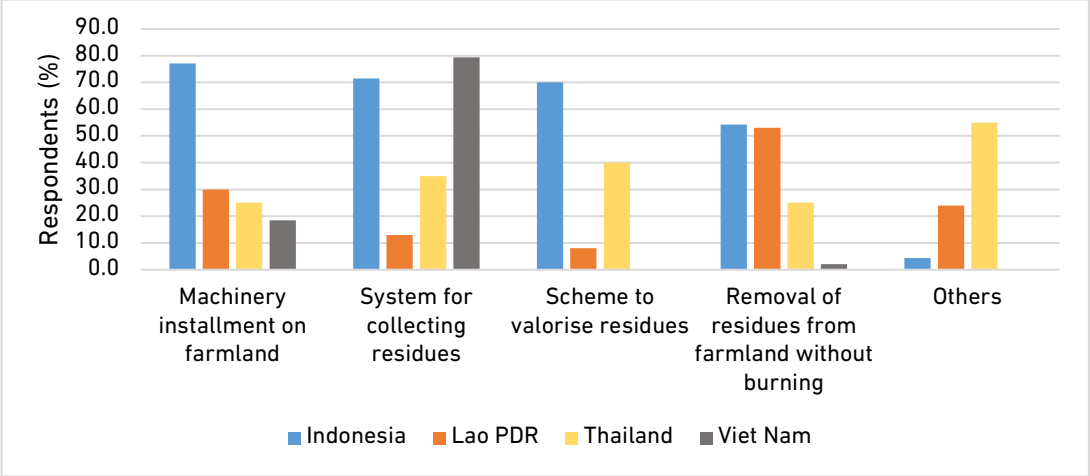
These approaches are selected with consideration of crop rotation requirements, while also supporting the continuity of cultivation, environmental sustainability, and economic efficiency. Only a small number of respondents (30%) identified using heavy machinery; they tend to be those with larger landholdings (over 10 hectares), as high operational costs remain a major barrier for most farmers.

Lao PDR is one of the major producers of cassava in ASEAN. However, 88.8% of the farmers still burned the agricultural residue. Other farmers employed large tractors to incorporate crop residues into the soil, while residues left on the field were managed through the application of herbicides for weed control.

Rice straw residue management in Thailand varies according to seasonal conditions. However, open-field burning remains one of the top three commonly practised methods for rice straw management by farmers. Crop burning reflects traditional residue disposal methods. During the wet season, farmers tend to chop and incorporate rice straw into the field, whereas in the dry season, the straw is typically baled and sold. Non-burning residue management practices offer potential economic benefits to farmers.

Cane trash management is mainly practised through open burning and vegetative mulching. Amongst the non-burning alternatives, vegetative mulching is the most common. Cane trash in Viet Nam is also frequently baled for biomass-based power generation, with some farmers using machinery for trash cutting. In Viet Nam, open burning for cane trash residue is considered the most effective and cost-efficient way for land preparation.

Figure 1.4. Respondents' Expectations of Technologies for Crop Residue Management



Lao PDR = Lao People's Democratic Republic.

Source: Authors' analysis.

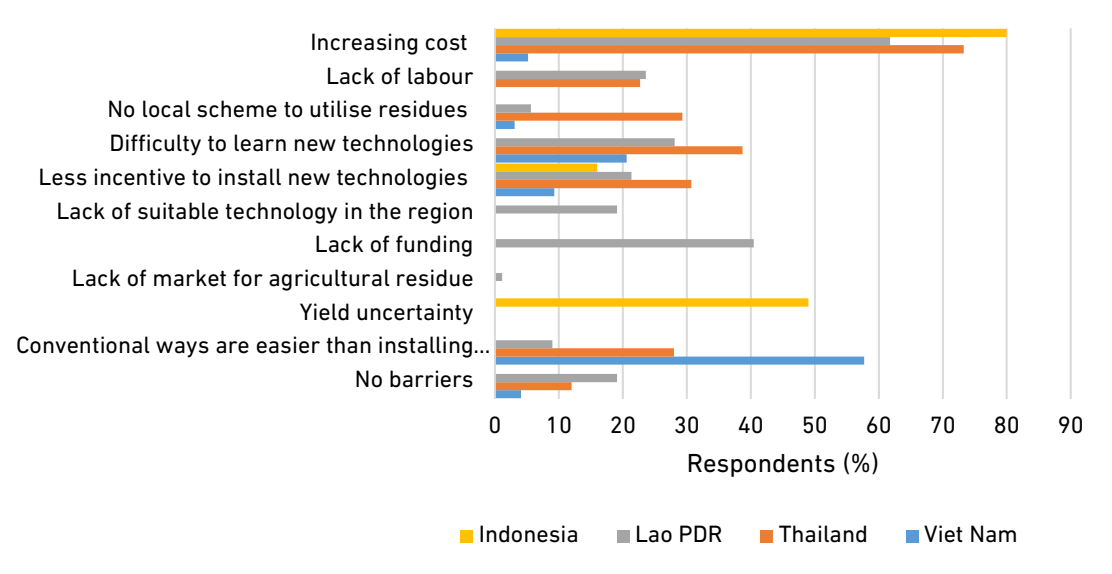
Figure 1.4. indicates that respondents in each country have different expectations regarding the technologies that could be widely implemented. In Indonesia, respondents expressed strong expectations for the installation of machinery on farmland and a system for collecting crop residues. In Lao PDR, respondents prioritised residue removal without burning, with farmland machinery installation identified as the next key expectation. This condition is influenced by the geographical characteristics of cassava cultivation, which is predominantly in mountainous areas, posing significant challenges for transporting residues to processing sites for alternative product development. Farmers in Thailand expected the other technologies, such as the use of urea and microorganisms to decompose rice straw. In Viet Nam, farmers express high expectations for the development of residue collection systems, where baled cane trash can be harnessed for power generation.

1.3.3. Challenges to Promoting a Reduction in Crop Burning

There are several challenges associated with the adoption of new technologies (Figure 1.5). The biggest obstacle is the high upfront costs, which affect production expenses. The remote and often hard-to-reach location of agricultural land poses a significant challenge for the collection and transportation of agricultural waste or crop residues to processing and treatment facilities. A lack of suitable machinery and equipment will slow down the broader adoption of alternative technologies.

Limited knowledge and inadequate human resource capacity also consistently hinder the adoption of new technologies in ASEAN. Limited market access for alternative products constrains farmers' willingness to adopt alternative practices. Last but not least, insufficient government support serves as a barrier to farmers' adoption of alternative technologies. Some farmers tend to be conservative and prefer to retain conventional practices over adoption of new technologies.

Figure 1.5. Challenges to Promote a Reduction in Crop Burning



Lao PDR = Lao People's Democratic Republic.

Source: Authors' analysis.

1.3.4. Solutions to Promote a Reduction in Crop Burning

The study showed that there is not a one-size-fits-all solution (Table 1.4). Each country has different possible solutions to overcome the challenges. In Thailand and Indonesia there is a strong need for financial support, such as government subsidies, incentives for farmers who practice more environmentally friendly technologies or activities. Financial assistance, such as support for the procurement of suitable machinery, is essential to enable farmers to adopt new technologies without adding a financial constraint. These findings emphasise the necessity of an appropriate financial scheme for the reduction of crop burning.

Pilot instalments and scaling-up processes get much attention in Lao PDR and Viet Nam. The successful implementation of potential solutions requires that farmers and relevant stakeholders fully recognise the importance of reducing crop burning. The study

underscores the necessity of targeted activities to raise awareness of crop-burning reduction. Capacity building and knowledge-sharing programmes can serve as effective strategies to enhance the quality of human resources. Capacity building and knowledge-sharing programmes can be enhanced through the strengthening of agricultural extension services, which serve as a critical channel for disseminating innovations and promoting sustainable farming practices.

Table 1.4. Solutions to Promote Crop-Burning Reduction in ASEAN Member States

No.	AMS	Type of crop	Applied technology
1	Indonesia	Oil palm	- Financial support (70.0%) - Capacity building and knowledge-sharing (55.7%) - Activities for raising awareness of crop-burning reduction (42.9%)
2	Lao PDR	Cassava	- Pilot instalment and scaling-up process (19.4%) - Capacity building and knowledge-sharing (16.4%) - Strengthen agricultural extension services (11.9%) - Local scheme for utilising residues (10.4%) - Co-generate energy by using biomass and agricultural waste (7.5%) - Awareness campaign on health and environmental impacts (7.5) - Diversification of crops (5.9%) - Specific period burning (5.9%) - Market for products of crop residue (4.5%) - Subsidy for machinery equipment for reducing crop burning (2.9%) - Financial support (1.5%)
3	Thailand	Rice	- Financial support (81.3%) - Capacity building and knowledge-sharing (65.4%) - Activities for raising awareness of crop-burning reduction (53.3%) - Pilot instalment and scaling-up process (48%) - Local scheme for utilising residues (42.7%) - Supporting regulation (1.3%)
4	Viet Nam	Sugarcane	- Pilot instalment and scaling-up process (47.3%) - Activities for raising awareness of crop-burning reduction (31.2%) - Local scheme for utilising residues (17.2%) - Financial support (4.3%)

AMS = ASEAN Member State; ASEAN = Association of Southeast Asian Nations; Lao PDR = Lao People's Democratic Republic.

Source: Authors' analysis.

1.3.5. Supporting Policies to Reduce Crop Burning

Supporting policies are necessary to boost initiatives in crop-burning reduction. Policies provide direction to identify the priorities, as well as create enabling environments. Moreover, policies facilitate collaboration between the government, private sector, and civil society to avoid duplication and fragmentation. The study shows that some countries have specific policies to support the reduction of crop burning.

Table 1.5. Existing Policies for Reducing Crop Burning in ASEAN Member States

AMS	Policy	Notes
Indonesia	- MoU forest fire prevention and law enforcement against wildlife crimes. - *Regulation of the Minister of Agriculture of the Republic of Indonesia No. 47 of 2014 on the Brigade and Implementation Guidelines for the Prevention and Control of Land and Plantation Fires.* - *Regulation of the Director General of Climate Change Control No. 12 of 2020 on the Standard Operating Procedures for Forest and Land Fire Control Activities.*	- Collaboration between Ministry of Forestry and National Police (Polri).
Lao PDR	- Local regulation - Slash-and-burn prohibition - Deforestation - Community monitor - Environmental protection - Agri fire management - Land and agriculture planning - Climate change - Air quality management - Control open burning - Dust control - Clean air	
Thailand	- *Environmental Protection and Promotion Act B.E. 2535 (1992).*	- This overarching legislation addresses environmental protection and pollution control, including provisions related to open burning

	- *Clean Air Act B.E. 2535 (1992).* - *Ministerial Regulation on the Control of Open Burning B.E. 2555 (2012).* - *Thai Agricultural Standard (TAS 4408-2022) for Sustainable Rice.* - *Draft Climate Change Act.* - *Royal Decree on Air Quality Management in Residential Areas B.E. 2553 (2010).* - Local regulations and bylaws.	and its impact on air quality. - This Act focuses on the control and prevention of air pollution, encompassing regulations related to emissions and open burning activities that may contribute to air pollution. - Issued under the authority of the Ministry of Natural Resources and Environment, this regulation provides specific guidelines and controls for open burning activities, including those related to agricultural practices. - TAS 4408-2022 aims to promote environmentally friendly and sustainable practices in rice production. This standard emphasises reducing environmental impacts associated with traditional rice production practices, including straw burning, which contributes to air pollution and greenhouse gas emissions. - Thailand is drafting the *Climate Change Act* and expects it to be implemented by 2025. This legislation is meant to support the country's goal of achieving net-zero emissions by 2065. The Act also aims to reduce greenhouse gas emissions across various sectors, including agriculture. Since straw burning contributes to air pollutants and

		greenhouse gas emissions, this Act supports measures that encourage sustainable agricultural practices. - Although primarily focusing on residential areas, this Royal Decree may include standards and regulations related to air quality management, indirectly impacting open burning practices. - Provinces, municipalities, or local authorities may have specific regulations or bylaws addressing open burning practices. Local ordinances can vary, and it is essential to consider regional variations in regulations.
Viet Nam	- *The National Assembly: the Law on Environmental Protection, Law No. 72/2020/QH* - *Penalties for Administrative Environmental Protection Offences, Decree No.45/2022/NĐ-CP* - Provincial regulations and bylaws	

AMS = ASEAN Member State; ASEAN = Association of Southeast Asian Nations; B.E. = Buddhist Era; Lao PDR = Lao People's Democratic Republic; MoU = memorandum of understanding; TAS = Thai Agricultural Standard.
Source: Authors' analysis (based on study findings).

Some countries have specific regulations for reducing crop burning (Table 1.5). Thailand has established advanced regulations that address not only agricultural production but also climate change adaptation. Indonesia, Lao PDR, and Viet Nam have developed regulations aimed at preventing crop burning and imposing penalties on violators. The study revealed the gap in the implementation of the policies. Although most of the respondents were aware that the policies existed, only a few of them knew the details of the policies. For instance, in Viet Nam, 70.1% of the respondents who were aware of the existing policies did not recognise that these policies were intended to reduce crop burning. In Indonesia, 58.6% of the

respondents were aware of the regulation that prohibits crop burning; however, they could not specify the name of the regulation. In Lao PDR, most of the respondents emphasised the significance of local regulations that prohibit slash-and-burn practices and deforestation, which have been well publicised. Respondents recommended stronger support for policy enforcement at the local level, along with the establishment of pilot models for small-scale farms in rural areas to facilitate knowledge-sharing and the exchange of best practices.

1.4. Conclusion

According to implemented policies and initiatives, collaboration between the public sector and the private sector is necessary to combat crop-burning practices. However, this is only required for promotion of alternative practices; for practitioners, profit is the fundamental requirement to reduce crop burning. Valorising crop residue is effective in improving profit for farmers and related actors in crop residue management. Theoretically, expanding and/or diversifying the market for residues is required to increase profits.

Application of technology is necessary as well, even for economic reasons, because some technologies reduce the cost of crop residue management, and valorise residues. It is crucial that appropriate implementation should include not only technology and related infrastructure, but also policy maintenance and activities for dissemination.

Drawing on insights from the literature and the surveys conducted in ASEAN countries, key challenges and actions are identified. For instance, the study highlighted that the economic issues of adopting alternative measures, such as installing machinery, are significant barriers. To facilitate adoption, a more effective strategy to promote the new installation technologies is needed. This effort can be supported by reducing the high upfront cost through subsidies or financial assistance. Training and capacity building are also key to supporting knowledge transfer as the new technology is adopted.

Government support, including aligning policy and regulatory frameworks are the most important step to enhance the adoption and implementation of alternative measures. Additionally, disseminating good practice further encourages the use of alternative technologies. All these initiatives need a multi-stakeholder approach, and private sector engagement is also important. The products arising from the alternative technologies need a market. Multi-stakeholder collaboration could foster markets for sustainable agricultural products and facilitate the development of carbon credit markets.

Joint initiatives between the government and related stakeholders are needed that balance policy, technological innovation, and market access to create a comprehensive framework for reducing crop burning. Last, developing a comprehensive monitoring and evaluation framework is essential to ensure the effective adoption of crop-burning reduction initiatives, ensure compliance with regulations, and inform evidence-based policy adjustments.

References

Asian Development Bank (ADB) (2023), *SAEL Biomass Energy Project: Report and Recommendation of the President*. Mandaluyong: ADB. https://www.adb.org/projects/documents/ind-56276-001-rrp

Association of Southeast Asian Nations (ASEAN) (2003), *Guidelines for the Implementation of the ASEAN Policy on Zero Burning*. Jakarta: ASEAN Secretariat. https://asean.org/book/guidelines-for-the-implementation-of-the-asean-policy-on-zero-burning/

––– (2004), *Guidelines for the Implementation of Controlled Burning Practices*. Jakarta: ASEAN Secretariat. https://environment.asean.org/fresources/detail/guidelines-for-the-implementation-of-controlled-burning-practices

––– (2015), *ASEAN Regional Guidelines for Promoting Climate Smart Agriculture (CSA) Practices*. Jakarta: ASEAN Secretariat. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.asean.org/wp-content/uploads/images/2015/October/ASEAN-Regional-Guidelines-on-Promoting-CSA-Practices/ASEAN%20Regional%20Guidelines%20on%20Promoting%20CSA%20Practices-endorsed%2037th%20AMAF.pdf

––– (2017), *ASEAN Regional Guidelines for Promoting Climate Smart Agriculture (CSA) Practices Volume II.* Jakarta: ASEAN Secretariat. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://asean.org/wp-content/uploads/2012/05/19.-CSA-Guidelines-Vol-2-for-ASEAN-Website.pdf

––– (2019), *ASEAN Strategy on Sustainable Biomass Energy for Agriculture Communities and Rural Development in 2020-2030*. Jakarta: ASEAN Secretariat. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://asean.org/wp-content/uploads/2021/12/FAFD-53.-Biomass-Energy-Strategy-ASEAN-2020-2030-Final-Draft-210820.pdf

––– (2022a), *ASEAN Regional Guidelines for Promoting Climate-Smart Agriculture (CSA) Practices Volume 3*. Jakarta: ASEAN Secretariat. https://asean.org/book/asean-regional-guidelines-for-promoting-climate-

smart-agriculture-csa-practices-volume-iii/

——— (2022b), *ASEAN Regional Guidelines for Sustainable Agriculture in ASEAN*. Jakarta: ASEAN Secretariat. https://asean.org/book/asean-regional-guidelines-for-sustainable-agriculture-in-asean-developing-food-security-and-food-productivity-in-asean-with-sustainable-and-circular-agriculture/

——— (2023), *ASEAN Strategy for Carbon Neutrality*. Jakarta: ASEAN Secretariat. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://asean.org/wp-content/uploads/2023/08/Brochure-ASEAN-Strategy-for-Carbon-Neutrality-Public-Summary-1.pdf

——— (2024a), *Action Plan for Sustainable Agriculture in ASEAN*. Jakarta: ASEAN Secretariat. https://asean.org/action-plan-for-sustainable-agriculture-in-asean/

——— (2024b), *ASEAN Guidelines on the Reduction of Crop Burning*. Jakarta: ASEAN Secretariat. https://asean.org/book/asean-guidelines-on-the-reduction-of-crop-burning/

Bahşi, K., B. Ustaoğlu, S. Aksoy, and E. Sertel (2023), 'Estimation of Emissions from Crop Residue Burning in Türkiye Using Remotely Sensed Data and the Google Earth Engine Platform', *Geocarto International,* 38(1), 2157052. https://doi.org/10.1080/10106049.2022.2157052

Bai, B., H. Zhao, S. Zhang, X. Li, X. Zhang, and A. Xiu (2022), 'Forecasting Crop Residue Fires in Northeastern China Using Machine Learning'. *Atmosphere*, 13(10), pp.1616–31. https://doi.org/10.3390/atmos13101616

Bhuvaneshwari, S., H. Hettiarachchi, and J.N. Meegoda (2019), 'Crop Residue Burning in India: Policy Challenges and Potential Solutions'. *International Journal of Environmental Research and Public Health*, 16(5), p.832. https://doi.org/10.3390/ijerph16050832

Climate and Clean Air Coalition (CCAC) (2019), *Increasing Agricultural Climate Action & Ambition*. Paris: CCAC Secretariat. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ccacoalition.org/sites/default/files/resources/2019_infosheet_initiative_agriculture_EN.pdf

Chandra, R., H. Takeuchi, and T. Hasegawa (2012), 'Methane Production from Lignocellulosic Agricultural Crop Wastes: A Review in Context to Second Generation of Biofuel Production'. *Renewable and Sustainable Energy Reviews*, 16(3), pp.1462–76. https://doi.org/10.1016/j.rser.2011.11.035

Chawla, D.S. (2022), 'A Conversation with Ashok Kumar Singh'. *ACS Central Science*, 8(2), pp.140–41. https://doi.org/10.1021/acscentsci.2c00095

Economic Research Institute for ASEAN and East Asia (ERIA) (2024), *Addressing Complex Challenges of Decarbonisation in Asia*. Jakarta: ERIA. https://www.eria.org/database-and-programmes/topic/asia-zero-emission-center/about

Einarsson, R. and U.M. Persson (2017), 'Analyzing Key Constraint to Biogas Production from Crop Residues and Manure in the EU – A Spatially Explicit Model'. *PLoS ONE*, 12(1), e0171001. https://doi.org/10.1371/journal.pone.0171001

European Commission (2023), *Approved 28 CAP Strategic Plans (2023-2027) Summary Overview for 27 Member States Facts and Figures*. Brussels: European Commission. https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans_en

Food and Agriculture Organization of the United Nations (FAO) (2014), *FAO's BEFS Bioenergy & Food Security Approach Implementation Guide*. Rome: FAO. https://openknowledge.fao.org/items/1c64efa5-c420-44fc-8b4b-9c9ddda0179a

––– (2018), *Improved Charcoal Technologies and Briquette Production from Woody Residues in Malawi*. Rome: FAO. https://www.fao.org/wood-energy-info-portal/search/detail/en/c/1305686/

––– (2020) *Fuel Not Fire: from Burning Crop Waste to Bioenergy Finding Sustainable Uses for Crop Waste in India and Worldwide*. Rome: FAO. https://www.fao.org/newsroom/story/Fuel-not-fire-from-burning-crop-waste-to-bioenergy/en

Ferdous, S.N., X. Li, K. Sahoo, and R. Bergman (2023), 'Toward Sustainable Crop Residue Management: A Deep Ensemble Learning Approach'. *Bioresource Technology Reports* (22), pp.101421–31. https://doi.org/10.1016/j.biteb.2023.101421

Government of Madhya Pradesh (2025), *Conditions for Obtaining a Grant*. Bhopal: Government of Madhya Pradesh. https://farmer.mpdage.org/Home/subsidytermconditions# (only in Hindi).

Gutiérrez, M.V. and R.B. Robles (2023), *Large Scale Composting Unites: A Solution to Upscale Regenerative Agriculture?*. Wageningen: GOPA MetaMeta (The Water Channel) https://thewaterchannel.tv/thewaterblog/large-scale-composting-units-a-solution-to-upscale-regenerative-agriculture/

Ibitoye, S.E., T-C. Jen, R.M. Mahamood, and E.T. Akinlabi (2021), 'Densification of Agro-Residues for Sustainable Energy Generation: an Overview'. *Bioresources and Bioprocessing* (8), pp.75–93. https://doi.org/10.1186/s40643-021-00427-w

Indian Oil Corporation Limited (2025), *SATAT Sustainable Alternative Towards Affordable Transportation*. New Delhi: Indian Oil Corporation. https://iocl.com/pages/satat-overview

Jameel, M.K. et al. (2024) 'Biogas: Production, Properties, Applications, Economic and Challenges: A Review'. *Results in Chemistry* (7), 101549. https://doi.org/10.1016/j.rechem.2024.101549

Kamal, N (2023), 'PepsiCo India Extends Pilot Initiative in Punjab to Address Stubble Burning', *Times of India*, 21

March..https://timesofindia.indiatimes.com/city/chandigarh/pepsico-india-extends-pilot-initiative-in-punjab-to-address-stubble-burning/articleshow/98867789.cms

Kaur, M., D. Singh, A. Anand, and T. Singh (2023), 'Do Attributes of Happy Seeder Technology Influence its Adoption Speed? An Investigation Using Duration Analysis in Northern India', *International Journal of Agricultural Sustainability*, 21(1). https://doi.org/10.1080/14735903.2023.2198324

Kozono, M., K. Yamada, and V. Anbumozhi (2025), *Building and Enhancing the Sustainable Agriculture and Food Systems in ASEAN Countries – A Preliminary Scoping Study*. Jakarta: ERIA. https://www.eria.org/research/preliminary-scoping-study-on-building-and-enhancing-sustainable-agriculture-and-food-systems-in-asean-countries

Kozono, M., K. Yamada, and S.M. Diyanah (2023), *Preliminary Scoping Study on Building and Enhancing Sustainable Agriculture and Food Systems in ASEAN*. Jakarta: ERIA. https://www.eria.org/research/building-and-enhancing-sustainable-agriculture-and-food-systems-in-asean-a-preliminary-scoping-study

Krishna, V. and M. Mkondiwa (2023), 'Economics of Crop Residue Management'. *Annual Review of Resource Economics,* 15, pp.19–39. https://doi.org/10.1146/annurev-resource-101422-090019

Kumar, P., D.M. Barrett, M.J. Delwiche, and P. Stroeve (2009), 'Methods for Pretreatment of Lignocellulosic Biomass for Efficient Hydrolysis and Biofuel Production', *Industrial & Engineering Chemistry Research*, 48(8), pp.3713–29. https://doi.org/10.1021/ie801542g

Lamba, S. and R.S. Gill (2024), 'Microbial Decomposer for Crop Residue Management in Rice-Wheat Cropping System', *Letters in Applied Microbiology*, 77(11). https://doi.org/10.1093/lambio/ovae106

Listman, M. (2020) '"Happy Seeder" Saves Farmers Money over Burning Straw, New Study in India Shows', Texcoco: International Maize and Wheat Improvement Center (CIMMYT). https://www.cimmyt.org/news/happy-seeder-saves-farmers-money-over-burning-straw-new-study-in-india-shows/

Lohan, S.K. et al. (2018), 'Burning Issues of Paddy Residue Management in North-West States of India', *Renewable and Sustainable Energy Reviews*, 81(1), pp.693–706. https://doi.org/10.1016/j.rser.2017.08.057

Mack, R., D. Kuptz, C. Schön, and H. Hartmann (2019), 'Combustion Behavior and Slagging Tendencies of Kaolin Additivated Agricultural Pellets and of Wood-Straw Pellet Blends in a Small-Scale Boiler'. *Biomass and Bioenergy*, 125, pp.50–62. https://doi.org/10.1016/j.biombioe.2019.04.003

Mishra, A.K., J. Hazrana, T. Yamano, N. Sato, and B.W. Arif (2024), 'Adoption of Farm Mechanization for Clean Air: Evidence from Farm Trials in Pakistan', *ADB Economics Working Paper Series*, 758.

https://www.adb.org/publications/farm-mechanization-clean-air-pakistan

Nature Conservancy, The (2021), *Promoting Regenerative And No-burn Agriculture (PRANA) to Tackle Climate Change in Northwest India*. Arlington: The Nature Conservancy. https://www.nature.org/en-us/about-us/where-we-work/india/our-priorities/prana/

Nayeem, J., M.M. Rahman, M.S. Jahan, and R.S. Popy (2023), 'Chapter 14 – Pulping and Papermaking of Rice Straw', in Z.M.A. Ainun, S.M. Sapuan, R.A. Ilyas (eds.), *Pulping and Papermaking of Nonwood Plant Fibres*, London. Academic Press, pp.245–65. https://doi.org/10.1016/B978-0-323-91625-7.00001-1

Nibber, G.S. (2022), 'Punjab Agriculture Dept Plans to Deploy Drones to Curb Farm Fires', *Hindustan Times,* 8 July. https://www.hindustantimes.com/cities/chandigarh-news/punjab-agriculture-dept-plans-to-deploy-drones-to-curb-farm-fires-101657304907356.html

Sain, M. (2020) 'Production of Bioplastics and Sustainable Packaging Materials Form Rice Straw to Eradicate Stubble Burning: A Mini-Review'. *Environment Conservation Journal*, 21(3), pp.1–5. https://doi.org/10.36953/ECJ.2020.21301

Saleem, M. (2022), 'Possibility of Utilizing Agriculture Biomass as a Renewable and Sustainable Future Energy Source', *Heliyon,* 8, e08905. https://doi.org/10.1016/j.heliyon.2022.e08905

Salma, A., L. Fryda, and H. Djelal (2024), 'Biochar: A Key Player in Carbon Credits and Climate Mitigation', *Resources*, 13(2), pp.31–43. https://doi.org/10.3390/resources13020031

Sarker, T.R., C.S. German, V.B. Borugadda, V. Meda, and A.K. Dalai (2023), 'Techno-Economic Analysis of Torrefied Fuel Pellet Production from Agricultural Residue via Integrated Torrefaction and Pelletization Process', *Heliyon*, 9, pp.e16359. https://doi.org/10.1016/j.heliyon.2023.e16359

Searle, S and K. Bitnere (2017), 'Review of the Impact of Crop Residue Management on Soil Organic Carbon in Europe', *International Council on Clean Transportation Working Paper 2017-15*. https://theicct.org/publication/review-of-the-impact-of-crop-residue-management-on-soil-organic-carbon-in-europe/

Shaikh, H. (2023), *Crop Residue Burning in Pakistan: A Systems Approach towards Sustainability. London*: International Growth Centre.https://www.theigc.org/blogs/climate-priorities-developing-countries/crop-residue-burning-pakistan-systems-approach

Sharma, A., and P.K. Singh (2023), 'Applicability of UAVs in Detecting and Monitoring Burning Residue of Paddy Crops with IoT Integration: A Step towards Greener Environment'. *Computers & Industrial Engineering*, 184(C), pp.109524. https://doi.org/10.1016/j.cie.2023.109524

Shyamusandar, P. et al. (2019), 'Fields on Fire: Alternatives to Crop Residue Burning in India', *Science,* 365(6453), pp.536–38. https://doi.org/10.1126/science.aaw4085

Singh, D.P. and R. Prabha (2017), 'Bioconversion of Agricultural Wastes into High Value Biocompost: A Route to Livelihood Generation for Farmers', *Advances in Recycling and Waste Management*, 2(3). https://doi.org/10.4172/2475-7675.1000137

Singh, S. (2017), 'How Inclusive and Effective are Farm Machinery Rental Services in India? Case Studies from Punjab', *Indian Journal of Agricultural Economics*, 72(3). https://doi.org/10.22004/ag.econ.302262

Smerald, A., J. Rahimi, and C. Scheer (2023), 'A Global Dataset for the Production and Usage of Cereal Residues in the Period 1997–2021'. *Scientific Data*, 10(685). https://doi.org/10.1038/s41597-023-02587-0

Strand, A., N. Skoglund, M. Thyrel, T.A. Lestander, M. Broström, and R. Backman (2019), 'Time-Resolved Study of Silicate Slag Formation During Combustion of Wheat Straw Pellets', *Energy Fuels*, 33, pp.2308–18. https://doi.org/10.1021/acs.energyfuels.8b04294

Svensson, A., M. Almarstrand, J. Axelsson, M. Nilsson, E. Timmerman, and G. Venkatesh (2024), 'Valorising Agricultural Residues into Pellets in a Sustainable Circular Bioeconomy'. *Problems of Sustainable Development*, 19, pp.272–78. https://doi.org/10.35784/preko.5803

United Nations Economic Commission for Europe (UNECE) (2022), *Guidance Document on Reduction of Emissions from Agricultural Residue Burning.* Geneva: United Nations. https://unece.org/sites/default/files/2023-03/2226205_E_PDF_WEB_0_0.pdf

United Nations Environment Programme (UNEP) (2021), *Toxic Blaze: the True Cost of Crop Burning*. Nairobi: UNEP. https://www.unep.org/news-and-stories/story/toxic-blaze-true-cost-crop-burning

United Nations Framework Convention on Climate Change (UNFCCC) (2023) *The People's Republic of China Fourth National Communication on Climate Change*. Bonn: United Nations. https://unfccc.int/sites/default/files/resource/China_NC4_English.pdf

United States Department of Agriculture (USDA) (2016), *Agronomy Technical Note #8 Nitrogen Management in a No-Till Corn System*. Washington, DC: USDA. https://efotg.sc.egov.usda.gov/references/public/IN/Technical_Note_8_Agronomy_NoTill_Nitrogen_Management.pdf

World Bank (2016), *Program Appraisal Document on a Proposed Loan in the Amount US$500 Million to the People's Republic of China for a Hebei Air Pollution Prevention and Control Program*. Washington, DC: World Bank. https://documents1.worldbank.org/curated/en/903471468198528220/pdf/China-Hebei-Air-Pollution-Prevention-and-Control-Program-Project.pdf

–––. (2023) *Uttar Pradesh Agriculture Growth and Rural Enterprise Ecosystem*

Strengthening Project. Washington, DC: World Bank. https://projects.worldbank.org/en/projects-operations/project-detail/P178253

Yamada, K. and V. Anbumozhi (2025), *Financial Strategies for Mitigating Crop Burning in the ASEAN Region,* 2025(14). Jakarta: ERIA. https://www.eria.org/publications/financial-strategies-for-mitigating-crop-burning-in-the-asean-region

Chapter 2

Introduction to Country Case Studies

Kentaro Yamada

2.1 Background

Reducing carbon emissions into the atmosphere to mitigate climate change is one of the most urgent global issues. Agriculture has been one of the largest sources of greenhouse gases and many activities have been implemented to reduce these emissions. The reduction of greenhouse gases from agriculture-related activities has been proposed as one of the key strategies in the '*ASEAN Regional Guidelines for Sustainable Agriculture in ASEAN: Developing Food Security and Food Productivity in ASEAN with Sustainable and CircularAgriculture'* which was adopted at the 44th Meeting of the Association of Southeast Asian Nations (ASEAN) Ministers on Agriculture and Forestry in 2022 (ASEAN, 2022). A follow-up study revealed that reducing greenhouse gas emissions and recycling agricultural waste biomass are relatively prioritised amongst the key strategies by the stakeholders of agricultural supply chains in ASEAN (Kozono et al., 2025).

Given the importance of reducing greenhouse gas emissions, the 45th ASEAN Ministers on Agriculture and Forestry Meeting agreed to develop the *ASEAN Guidelines for Reduction of Crop Burning in ASEAN* (hereafter, referred to as 'the Guidelines') as one of the Priority Economic Deliverables of the Lao People's Democratic Republic's ASEAN Chairmanship in 2024 (ASEAN Secretariat, 2023).

The Guidelines are developed to provide ASEAN Member States the policy recommendations to:

- decrease environmental degradation such as the rising levels of air, water, and land pollution caused by crop-burning practices, and encourage safe and sustainable alternatives to crop burning to minimise the negative impacts on both public health and the natural environment;
- mitigate greenhouse gas emissions by promoting sustainable practices that minimise or eliminate the need for crop-burning practices and contributing to the region's commitment to climate action; and
- promote sustainable agriculture that is socially, economically, and environmentally viable, encouraging the adoption of alternative techniques such as non-burning agricultural practices, conservation agriculture, no-till farming, and utilisation of crop residues for developing products with

commercial potential.

To support the implementation of the Guidelines, practices for reducing crop burning should be provided. Crop burning has a wide range of definitions and there are various practices for reducing crop burning. The case studies into oil palm cultivation in Indonesia, cassava production in the Lao People's Democratic Republic, rice production in Thailand, and sugarcane production in Viet Nam are conducted by a literature survey and questionnaire survey. They seek to identify current activities, issues, and possible solutions to reduce crop burning.

2.2 Methods

For this study a literature review was undertaken, including academic papers and political documents for each country, to support the assessment of each case and the analysis of the results of questionnaire survey.

A field survey with relevant stakeholders and enablers was conducted through interviews and questionnaires. The contents of the questionnaire are aligned with the Guidelines and were determined by all the authors of this report (Appendix), refining the details to fit each country case. Questionnaire surveys were conducted through in-person interviews and online. Approximately 70 stakeholders along the value chain of each crop in each country were interviewed. The results are categorised into policies and initiatives, foundational systems, technologies and techniques, and capacity building. The challenges and possible solutions for each category are explored at the farm-level and national level.

The surveys for compiling all data and information were carried out between August 2024 and March 2025.

Chapter 3
Case Study on Reducing Crop Burning in ASEAN Member States: Oil Palm in Indonesia

A Faroby Falatehan

3.1 Introduction

Indonesia, one of the world's leading producers of palm oil, has faced a persistent and escalating crisis in the form of fires ravaging its oil palm plantations. These fires, which occur annually, have devastating consequences for the environment, human health, and the economy. The underlying causes of these fires are complex and multifaceted, involving both natural and human-induced factors.

The primary cause of fires in oil palm plantations is the traditional slash-and-burn method used to clear land for new plantings. This technique, although cost-effective for small farmers, is highly dangerous and can easily spiral out of control, especially during the dry season. In addition to slash-and-burn, illegal land-clearing activities by large-scale plantations contribute significantly to the problem. These fires often spread to peatlands, which are highly combustible and release massive amounts of carbon dioxide when burned, exacerbating global climate change.

The impact of these fires on the environment is profound. They lead to significant deforestation, loss of biodiversity, and destruction of wildlife habitats. The smoke and haze from the fires also have severe repercussions for air quality, both locally and regionally, affecting neighbouring countries like Malaysia and Singapore. The toxic haze poses a serious health risk to millions of people, leading to respiratory problems and other health issues, particularly amongst vulnerable populations such as children and the elderly.

Efforts to address this crisis have been undertaken at various levels, including government policies, international co-operation, and corporate commitments. The Government of Indonesia has implemented stricter regulations and penalties for illegal burning, as well as initiatives to promote sustainable palm oil production. International organisations and non-governmental organisations (NGOs) are working to support these efforts through funding, capacity building, and raising awareness. Additionally, some palm oil companies are adopting more sustainable practices and seeking certification through the Roundtable on Sustainable Palm Oil.

Despite these efforts, challenges remain to effectively curb the fires. Enforcement of regulations is often hampered by corruption and lack of resources. There is also

a need for greater collaboration between all stakeholders, including local communities, government agencies, and the private sector. Addressing the root causes of the fires, such as land tenure issues and providing alternative livelihoods for small farmers, is crucial for a long-term solution. Continued vigilance and commitment to sustainable practices are essential to protect Indonesia's forests and mitigate the adverse impacts of these fires.

To identify the current status of oil palm residue burning in Indonesia and provide proposals to reduce burning, a case study was conducted. The study comprises a literature review, questionnaire survey, and analysis of the findings.

3.2 Literature Review

3.2.1 The Situation in Indonesia

Indonesia, one of the world's leading producers of palm oil, has faced a persistent and escalating crisis in the form of fires ravaging its oil palm plantations. These fires, which occur annually, have devastating consequences for the environment, human health, and the economy. The underlying causes of these fires are complex and multifaceted, involving both natural and human-induced factors.

Palm oil has become the flagship product in the plantation business in Indonesia (Falatehan and Siswanto, 2014). Over the past 5 years, Indonesia has maintained its position as one of the world's leading producers of palm oil. The production figures have shown some fluctuations due to various factors such as weather conditions, government policies, and global market demand. During 2020–2021, Indonesia produced approximately 43.5 million metric tonnes of crude palm oil (CPO). This figure slightly decreased to 42.0 million metric tonnes during 2021–2022 but rebounded to 45.0 million metric tonnes during 2022–2023. The production then saw a minor dip to 43.0 million metric tonnes during 2023–2024 before reaching an estimated 46.5 million metric tonnes during 2024–2025.

Table 3.1 refers to CPO production in Indonesia. Over the past 5 years, Indonesia has consistently been one of the world's largest CPO producers. The production figures have shown some fluctuations due to factors such as weather conditions, government policies, and global market demand. Despite these fluctuations, Indonesia's CPO industry remains a significant contributor to the country's economy, providing employment and generating substantial export revenues.

Table 3.1. Palm Oil Production in Indonesia over The Last 5 Years

(1,000 tonnes)

Year	Production
2020–2021	43,500
2021–2022	42,000
2022–2023	45,000
2023–2024	43,000
2024–2025	46,500

Source: USDA, 2025.

Indonesia's palm oil industry is characterised by a mix of large-scale plantations and smallholder farms. The government has implemented various initiatives to support sustainable palm oil production, including certification programmes and efforts to improve agricultural practices. These measures aim to address environmental concerns and ensure that palm oil production does not contribute to deforestation or other negative environmental impacts. The industry also faces challenges such as labour issues and the need for continuous improvement in productivity and sustainability.

Table 3.2. Oil Palm Plantation Area in Indonesia over The Last 5 Years

(million hectares)

Year	Land Area
2020	14.6
2021	14.8
2022	15.0
2023	15.2
2024	15.4

Source: Statista, 2025.

Over the past 5 years, the land area dedicated to oil palm plantations in Indonesia has steadily increased. In 2020, the total land area was approximately 14.6 million hectares, and by 2024, it had grown to around 15.4 million hectares. This expansion can be attributed to the growing demand for palm oil, both domestically and internationally, as well as the government's efforts to boost the industry. However,

this growth has also raised concerns about deforestation and its impact on biodiversity and local communities (Table 3.2).

The Government of Indonesia has implemented various measures to address these concerns, including a moratorium on new palm oil permits and promoting sustainable practices amongst producers. Despite these efforts, the industry continues to face challenges related to land use, environmental sustainability, and social issues. The balance between economic growth and environmental protection remains a critical issue for the future of Indonesia's palm oil sector.

Indonesia is currently intensifying oil palm plantations. In fact, according to President Prabowo Subianto, Indonesia needs to increase oil palm cultivation because palm oil is a strategic commodity, as many countries rely on Indonesia for palm oil supplies (Hasyim, 2025). Moreover, palm oil has many downstream products, one of which is energy, specifically biodiesel.

The use of fossil fuels is increasing along with population growth and the rapid pace of industrial development in the country. This has led to a fuel crisis, prompting a search for an alternative source of fuel that is cheaper and more readily available (Falatehan and Sari, 2020). In recent years, there has been a growing emphasis on the development of downstream industries to add value to palm oil products. This includes the production of biodiesel, oleochemicals, and other palm oil derivatives (Falatehan and Setiawan, 2020). The Government of Indonesia has been promoting the use of biodiesel as part of its energy diversification strategy, which has led to increased domestic consumption of CPO. As a result, the palm oil industry is expected to continue playing a crucial role in Indonesia's economic development while addressing sustainability and environmental concerns.

The high demand for palm oil has led to widespread land conversion into oil palm plantations. One of the easiest and cheapest ways to achieve this is through slash-and-burn methods. As already mentioned, the primary cause of fires in oil palm plantations is the traditional, cost-effective but highly dangerous slash-and-burn method used to clear land for new plantings. In addition to slash-and-burn, illegal land-clearing activities by large-scale plantations contribute significantly to the problem. These fires often spread to peatlands, which are highly combustible and release massive amounts of carbon dioxide when burned, exacerbating global climate change, increasing deforestation and loss of biodiversity, and creating a haze that affects air quality locally and regionally.

Over the past 5 years, Indonesia has experienced significant challenges with fires in oil palm plantations. These fires have been a recurring issue, causing extensive damage to the environment, human health, and the economy. Between January and October 2023 alone, nearly 1 million hectares (2.47 million acres) of land burned in

Indonesia (Jong, 2024). This increase in fires can be attributed to a combination of factors, including the El Niño weather phenomenon and the practice of burning land for new plantations. In 2020, it was reported that tropical forest and peatland areas larger than the Netherlands had burned in Indonesia over the past 5 years (Land Portal, 2020).

3.2.2 Types of Smallholder Oil Palm Farmers

According to Andrianto, et al. (2019), there are six typologies of independent smallholder oil palm farmers: migrant labourers, early adopters, entrepreneur, elites, subsistence farmers, and migrant farmers. These smallholders are generally characterised by self-managed, family-owned operations.

Migrant labourers, as noted by Adrianto, Fauzi, and Falatehan (2019), leveraged their shared experiences as overseas workers to build strong social bonds. These migrants exchanged information about available land for oil palm cultivation and played a role in overseeing plantation management. Early adopters, often respected elders and pioneers, possessed a deep knowledge of the land's history and used their social capital to influence development.

Entrepreneurs, who typically have weaker ties to local communities, sought to mitigate conflicts by fostering relationships with community members and local leaders. They achieved this by offering financial assistance and loans, creating a sense of dependence.

Elites — whether long-time residents or migrants — held significant positions in government and used both formal authority and informal influence to acquire and protect land. Their presence was generally welcomed by local communities, who viewed them as protective figures.

Meanwhile, subsistence farmers, representing the marginal segments of village society, formed farmer groups to collectively strengthen their position in securing land and managing farms. Migrant farmers also engaged in informal knowledge-sharing to reinforce their identity as committed agricultural and oil palm cultivators.

Smallholder oil palm farmers do play a role in the occurrence of fires in Indonesia, although their impact is often intertwined with larger systemic issues. Smallholders, who manage about one-quarter of Indonesia's oil palm plantations, often resort to slash-and-burn methods to clear land for new plantings. This practice is cost-effective for small farmers but highly dangerous and can easily get out of control, especially during the dry season.

The lack of resources and support for smallholders exacerbates the problem. Many small farmers do not have access to training, supervision, or financial support to

adopt more sustainable practices. As a result, they often use cheap, low-yield seedlings and burn land to make way for crops. This not only contributes to the occurrence of fires but also leads to lower productivity and sustainability concerns.

Efforts to address the issue of fires caused by smallholders include providing financial and technical support to help them to increase palm oil production on less land. This includes buying better agricultural inputs and adopting sustainable practices. However, the upfront costs for independent smallholder certification can be prohibitively expensive, making it challenging for small farmers to pursue sustainable palm oil production.

In summary, while smallholder farmers do contribute to the occurrence of fires in oil palm plantations, their activities are often driven by economic constraints and lack of support. Addressing these underlying issues is crucial for reducing the incidence of fires and promoting sustainable palm oil production in Indonesia.

3.2.3 Regulations to Address Fires in Indonesia

Indonesia has implemented a comprehensive set of regulations to address the issue of fires, particularly in oil palm plantations. These regulations are designed to prevent and control fires, protect the environment, and ensure the safety and health of the population. The primary laws include Law No. 41/1999 on Forestry, which holds concessionaires responsible for fires in their concessions, and Law No. 32/2009 on Environmental Protection and Management, which mandates absolute responsibility for environmental threats.

The Ministry of Environment and Forestry has also issued specific regulations to address land and forest fires. One such regulation is the Ministerial Regulation No. P.32/MENLHK/SETJEN/KUM.1/3/2016, which outlines procedures for preventing and controlling forest and land fires. This regulation emphasises the importance of early detection, rapid response, and community involvement in fire prevention efforts. Additionally, the Ministry has established guidelines for sustainable land management practices to reduce the risk of fires.

The Directorate General of Plantations, under the Ministry of Agriculture, has implemented regulations to promote sustainable palm oil production and prevent fires. These include the Indonesian Sustainable Palm Oil certification system, which sets standards for environmentally friendly and socially responsible palm oil production. The certification requires plantation companies to adopt best practices in land management, fire prevention, and environmental protection.

In addition to national regulations, local governments have also enacted policies to address fires. For example, the Governor of Central Kalimantan issued Regulation

No. 15/2010 on the prevention and control of forest and land fires. This regulation mandates the establishment of fire brigades, the use of firebreaks, and the implementation of community-based fire management programmes. Local governments play a crucial role in enforcing these regulations and ensuring compliance at the grassroots level.

Despite these efforts, challenges remain in effectively curbing fires in Indonesia. Enforcement of regulations is often hampered by corruption, lack of resources, and economic pressures on smallholder farmers. However, continued vigilance, collaboration amongst stakeholders, and commitment to sustainable practices are essential to protect Indonesia's forests and mitigate the adverse impacts of fires. The government's ongoing efforts to strengthen regulations and promote sustainable land management practices are crucial for achieving long-term solutions.

The issuance of regulations targeting fires in oil palm plantations in Indonesia brings with it several key expectations and hopes. First, there is a strong hope that these regulations will lead to a significant reduction in the incidence of fires. By holding plantation companies accountable and promoting sustainable land management practices, the government aims to prevent illegal land clearing and slash-and-burn methods that often lead to uncontrollable fires. The success of these regulations could result in healthier and more resilient ecosystems, reducing the environmental damage caused by recurrent fires

Second, the regulations are expected to improve air quality and public health both within Indonesia and in neighbouring countries affected by transboundary haze pollution. The toxic haze from fires poses serious health risks, leading to respiratory problems and other health issues. By effectively curbing fires, the regulations could ensure cleaner air and better health outcomes for millions of people, especially vulnerable populations such as children and the elderly.

Finally, these regulations aim to enhance Indonesia's international reputation and strengthen its commitments to global environmental goals, such as the United Nations Sustainable Development Goals. Demonstrating a commitment to sustainable palm oil production and environmental protection can attract international support, funding, and collaboration, boosting the country's efforts to achieve long-term environmental sustainability.

The expansion of oil palm plantations has brought economic and social benefits. However, conflicts emerged between companies and local communities when the government imposed a moratorium on new oil palm plantation permits on peatlands due to fire risks. Compared to mineral soils, peatlands offer lower productivity for oil palm cultivation. While it is possible to manage oil palm

plantations on peatlands, proper water regulation is crucial to ensure sustainability, as peatlands are highly vulnerable to environmental degradation (Sari et al., 2018).

The successful implementation of these regulations could position Indonesia as a leader in sustainable agriculture and forest management, setting an example for other palm oil-producing countries.

3.3 Study Methodology

This study in Indonesia focuses on smallholder oil palm farming. The survey was conducted in two regions: Tebo Regency in Jambi Province on the island of Sumatra and Sanggau Regency in West Kalimantan Province on the island of Kalimantan. A total of 70 respondents participated in the study across these areas, comprising stakeholders including farmers of the targeted crops.

The survey was carried out using a structured questionnaire. It was divided into eight sections: (i) respondent identity, (ii) farming status, (iii) opinions on crop burning, (iv) activities for crop-burning reduction, (v) crop-burning reduction policies, (vi) capacity building and knowledge-sharing, (vii) involving stakeholders, and (viii) technologies.

The results are categorised into four key areas: policies and initiatives, foundational systems, technologies and techniques, and capacity building. Additionally, the survey analysis incorporates empirical field data along with relevant references related to this study, which are examined using a descriptive approach.

Descriptive analysis is a method used in research to summarise, organise, and present data in a meaningful way. It focuses on describing the characteristics, patterns, and trends within a dataset without making inferences or predictions. This type of analysis helps researchers understand the basic features of the data by using statistical measures such as frequencies, percentages, mean, median, and standard deviation (Babbie, 2020).

According to Creswell and Cresswell (2018), in qualitative research, descriptive analysis involves categorising and interpreting observations, interviews, or textual data to provide a detailed account of a phenomenon. In quantitative research, it often includes graphical representations like charts, tables, and histograms to illustrate trends and distributions.

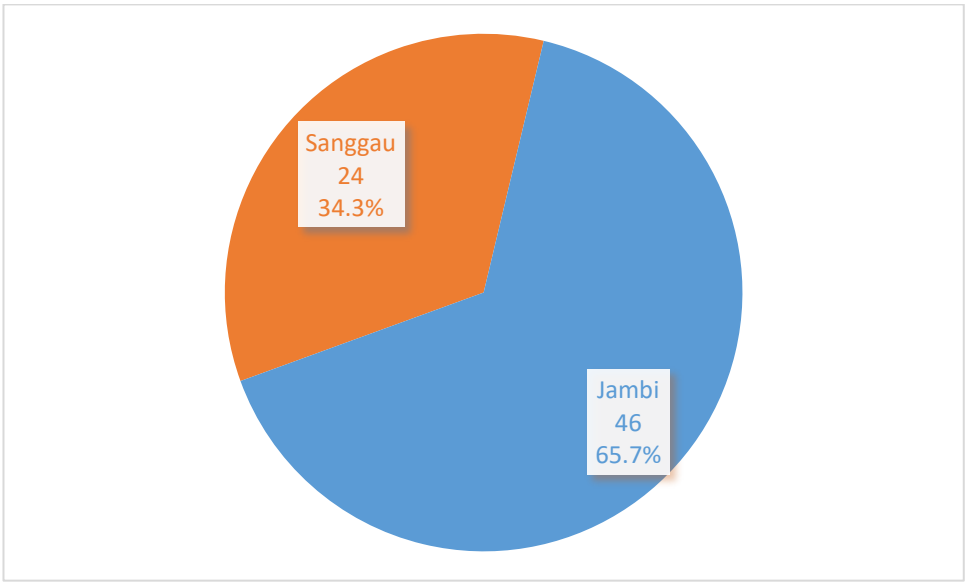
Overall, descriptive analysis provides a foundational understanding of the data, serving as a basis for further statistical analysis or decision-making.

3.4 Study Results and Discussion

3.4.1 Characteristics of Respondents

The study was conducted in two locations: Tebo Regency in Jambi Province, Sumatra, and Sanggau Regency in West Kalimantan Province, Borneo. A total of 70 respondents participated, with 24 individuals (34.3%) from Sanggau Regency and 46 individuals (65.7%) from Tebo Regency (Figure 3.1). Amongst the respondents, the majority (81.4%) work as farmers, while 8.6% are entrepreneurs and teachers and 1.4% are police officers (Table 3.4). Additionally, 2.9% of the respondents are female.

Figure 3.1. Share of Respondents



Source: Author's analysis, 2025.

The demographic characteristics of oil palm farmers in the study area reveal that the largest age group is between 40 and 49 years old, representing approximately 35.7% of the total farmer population. This is followed by those aged 30–39 (27.1%), 50–60 years (22.9%), and 20–29 (14.3%) (Table 3.3). There are relatively few young farmers, which may be due to a lack of interest amongst the younger generation in entering the agricultural sector. Regarding gender distribution, nearly 100% of the respondents are male.

Table 3.3. Age of Respondents

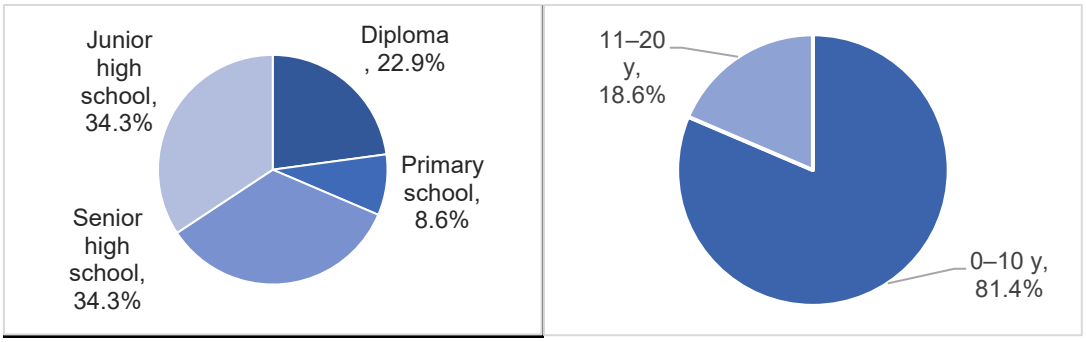
Age	Quantity	
	n	%
20–29	10	14.3
30–39	19	27.1
40–49	25	35.7
50–60	16	22.9
Total	**70**	**100.0**

n =.number of respondents.

Source: Author's analysis, 2025.

The majority of respondents have completed junior high school and high school education, each accounting for 34.3% of the total. This is followed by 22.9% with a diploma and 8.6% with only elementary school education (Figure 3.2). The relatively high proportion of farmers with higher education could have a positive influence on the development of more modern and sustainable agricultural practices, as they are generally more receptive to innovations and new technologies in oil palm cultivation. These demographic characteristics suggest significant potential for enhancing the efficiency and sustainability of the agricultural sector amongst oil palm farmers in Tebo and Sanggau Regencies. Additionally, most respondents (81.4%) have 11–20 years of farming experience (Figure 3.2).

Figure 3.2. Educational Background and Experience of Oil Palm Farming



y = year.

Source: Author's analysis, 2025.

The majority of oil palm farmers (81.4%) consider agriculture their primary occupation. This indicates their commitment to, and reliance on, this sector as their main source of livelihood. Meanwhile, the remaining farmers are engaged in other

professions, such as teachers and entrepreneurs, each accounting for 8.6%, which may suggest diversification of income sources beyond agriculture.

Table 3.4. Main Occupation of Respondents

Occupation	Quantity	
	n	%
Teacher	6	8.6
Farmer	57	81.4
Police	1	1.4
Business	6	8.6
Total	**70**	**100.0**

n = number of respondents.

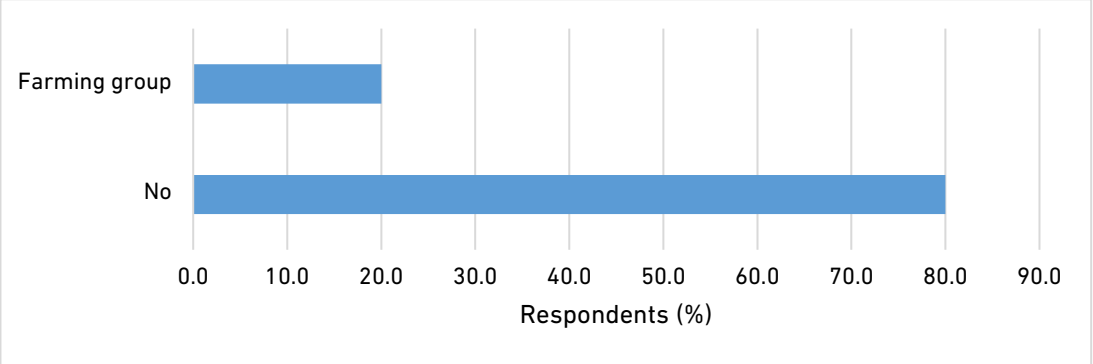
Source: Author's analysis, 2025.

In terms of organisation, only 20% of respondents are members of farmer groups (Figure 3.3). In general, the farmer groups do not function effectively due to limited institutional capacity caused by several factors.

- Many farmer institutions are developed sectorally by various ministries and local governments, resulting in small-scale and segmented organisations. Consequently, these institutions fail to strengthen farmers' bargaining power and competitiveness.
- Access to capital, technology, information, and markets remains limited. This may be because these farmers are independent. Additionally, inadequate infrastructure and low productivity further hinder the development of agricultural institutions (Falatehan, 2023).
- Innovations have not been fully adopted by small farmers due to a lack of adequate resources, including technology, financial support, and skilled human resources (Veronica et al., 2018). Knowledge management approaches can play a role in supporting and accelerating the innovation process in the agricultural sector.

Farmers with landholdings of 11–20 hectares make up 5.7%, while the rest own less than 5 hectares. This indicates that farmers in this region are generally independent, with a small amount of private land that does not exceed 10 hectares per farmer. This limited land size can impact farmers' production capacity and income.

Figure 3.3. Membership of Farmers' Associations



Source: Author's analysis, 2025.

3.4.2 Oil Palm Varieties Grown

There are various oil palm varieties, distinguished by their external appearance, shell thickness, and fruit skin colour. Farmers in both locations use Dura and Tenera seed varieties. The main difference between these two lies in the thickness of the fruit shell and other characteristics that affect oil production. According to Abdul (2023), the advantages of each variety are as follows:

Dura Seeds

- Thick shell: Dura fruits have a very thick shell, approximately 2–8 millimetres, which provides a strong protection for the palm kernel.
- Larger fruit size: Dura fruits are generally larger compared to other varieties.
- Higher palm kernel oil yield: Dura produces more palm kernel oil than Tenera, and it has a higher market value internationally.

Tenera Seeds

- Thin shell: Tenera fruits have a thinner shell, less than 2 millimetres, which increases the proportion of mesocarp (fruit flesh) that produces oil.
- Higher oil production: Due to its thin shell, Tenera has a higher oil yield per fruit.
- High extraction rate: Tenera is often used in the Smallholder Palm Oil Rejuvenation Programme due to its superior extraction rate.

These advantages influence farmers' decisions when selecting seeds for cultivation.

3.4.2.1 Land Clearing and Fire Use in Oil Palm Plantations

The issue of land clearing by burning aligns with Principle 7.9 (RSPO, 2018), which prohibits the use of fire for land clearing and encourages its avoidance in managed areas. Regarding land-clearing methods, most farmers do not use burning, with 66 farmers (94.3%) avoiding this practice. Only four farmers (5.7%) admitted to burning crop residues before replanting. This reflects a high awareness of environmental sustainability, soil health, and the risks of fire that could damage land and crops.

Independent farmers have increasingly reduced burning activities since the Government of Indonesia introduced the 'zero-burning' policy (Government of Indonesia, 2014). This policy aims to prevent forest fires and hazardous haze that affects human health and the environment. Land burning often leads to massive forest fires, especially in peatland areas.

3.4.2.2 Government Monitoring and Enforcement

Forest monitoring in Indonesia has been strengthened through a collaboration between the Ministry of Forestry and the National Police (Polri). This partnership aims to maximise forest protection efforts and enforce laws against forestry-related violations.

In 2025, the Ministry of Forestry and Polri signed an extension of their memorandum of understanding, covering areas such as forest fire prevention and law enforcement against wildlife crimes. With Polri's extensive network reaching rural areas, this collaboration is expected to improve monitoring effectiveness and legal enforcement in the field.

However, this policy also presents challenges for small-scale farmers, who have long relied on limited burning as a traditional practice. They now have to seek alternative methods for land clearing, which are often more expensive and time-consuming.

3.4.2.3 Land-Clearing Costs and Methods

Based on past experiences, land-clearing costs vary:

- 41% of farmers spent Rp1,000,000[2] per hectare.

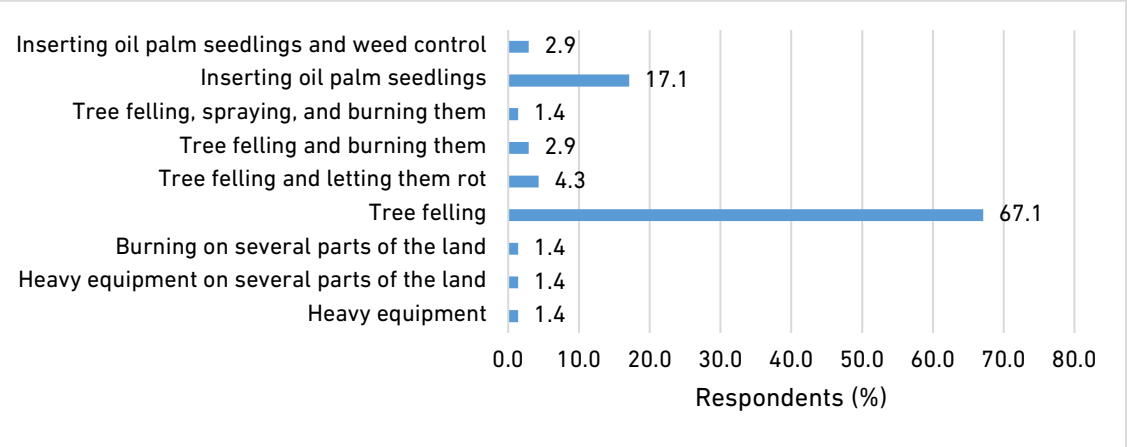
[2] Rp = rupiah.

- 17% incurred zero costs by exchanging felled timber for logging services.
- 14% spent Rp2,000,000 per hectare.
- The average cost for land clearing was Rp1,945,714.

The average land-clearing cost estimated in this study is consistent with the findings of Dwijanarko et al. (2020), who reported an average cost of approximately Rp1,260,000 per hectare for non-burning land clearing in Tanah Laut District, South Kalimantan.

Farmers employ several methods for land preparation in oil palm plantations, including tree felling, spraying, weeding, and intercropping oil palms with rubber trees. The most commonly used method is tree felling (67.1%), followed by intercropping with rubber (17.1%). Only 2.9% of farmers use heavy machinery, indicating that most rely on simpler and more environmentally friendly traditional methods (Figure 3.4).

Figure 3.4. Respondents' Experiences of Crop Residue Management



Source: Author's analysis, 2025.

These farmers carry out burning activities to develop new land, specifically to become oil palm plantations. The majority of the previous crops planted by the farmers were rubber, accounting for 75.7%, followed by pepper at 20.0%, and forest plants at 1.4% (Table 3.5).

Table 3.5. Crops Cultivated by Respondent's Prior to Oil Palm

Crop	Quantity	
	n	%
Rubber	53	75.7
Pepper	14	20.0
Forest Tree	1	1.4
(blank)	2	2.9
Grand Total	70	100.0

n = number of respondents.

Source: Author's analysis, 2025.

In handling oil palm crop residues during replanting, most farmers use manual methods or chainsaws for cutting and shredding palm trunks. Out of 70 respondents, 23 had experience with replanting. This aligns with a study conducted by Astiti, Falatehan, and dan Putri (2022) on oil palm replanting at Village Unit Cooperative/Koperasi Unit Desa Tunas Muda Riau, which found that farmers carried out gradual cutting and shredding using chainsaws. This approach was chosen because the farmers considered crop rotation, ensuring the continuity of cultivation. Additionally, by doing it in stages, they could reduce costs. The shredded crop residues are either stored within the plantation to later decompose into fertiliser or moved to the edges of the plantation, where they naturally decay over time (Table 3.6).

Meanwhile, only a few respondents used heavy machinery, mainly those with larger landholdings (more than 10 hectares). This is due to the high costs associated with using heavy equipment. A study by Rosyadi (2023) highlighted that independent farmers often struggle with the inefficiency and high costs of replanting, which is a necessary part of managing their oil palm plantations. The significant expenses incurred are largely due to the rental costs of excavators for felling and shredding old or dead oil palm trees. On average, the cost of handling oil palm crop residues is Rp527,143.

Table 3.6. Methods of Handling Palm Oil Residue (Trunk)

Methods of Handling	Quantity	
	n	%
Rolled with a heavy roller to crush the weeds into the soil surface	5	21.7
Burned and spread in the field	0	0.0
Burned in a pile	0	0.0
Removed from the field for other uses	11	47.8

Others	7	30.5
Total	**23**	**100.0**

n = number of respondents.

Source: Author's analysis, 2025.

Handling the remnants of oil palm trees, particularly the trunks, involves several methods to ensure environmental sustainability and economic efficiency. One common approach is to use the old palm trunks as mulch or compost. This not only helps to enrich the soil with organic matter but also improves soil structure and fertility. The trunks are shredded and spread over the plantation area, which helps to retain soil moisture and reduce weed growth (Figure 3.5). The figure shows the process of destroying and shredding old oil palm trunks using excavators in an oil palm plantation area. This activity is commonly carried out during oil palm replanting programs after the old trees have been felled. The shredded palm trunks are left on the ground surface to naturally decompose, which helps improve soil organic matter, maintain soil moisture, and reduce the need for open burning practices under the *zero-burning technique*. This method also supports more sustainable and environmentally friendly plantation management.

Another method is to convert the palm trunks into bioenergy. The biomass from the trunks can be processed into bioethanol, biobriquettes, or biogas. This not only provides a renewable energy source but also helps in reducing the carbon footprint of the palm oil industry. Additionally, the trunks can be used to produce bioplastics, which are biodegradable and environmentally friendly alternatives to conventional plastics.

Last, the trunks can be utilised in the production of animal feed. The fibrous material from the trunks can be processed and mixed with other feed ingredients to create a nutritious feed for livestock. This method not only helps in managing the waste but also provides an additional revenue stream for palm oil producers (Falatehan, Falatehan, and Hariyadi, 2023).

Figure 3.5. Palm Trunks Rolled with a Heavy Roller to Crush them into the Soil Surface

Source: PKT Group, 2023.

3.4.3 Respondents' Perceptions of the Impacts of Crop Burning

Most respondents stated that burning activities have an environmental impact, with 60.0% indicating that the impact is negative. Of the remainder, 18.6% stated that burning has no environmental impact and the rest did not provide a clear answer (Table 3.7).

Table 3.7. Respondents' Perceptions of the Impact of Crop Burning

Answer	Quantity	
	n	%
Negative impact	42	60.0
Positive impact	13	18.6
No answer	15	21.4
Total	**70**	**100.0%**

n = number of respondents.

Source: Author's analysis, 2025.

The issue of burning vegetation for oil palm land clearing has raised various concerns amongst farmers. Based on respondents' answers – where they could select more than one response – a total of 148 responses as recorded (Table 3.8).

- 33.1% of respondents stated that burning leads to lower crop yields. This aligns with a study by Safitri et al. (2024), which found that burning damages soil structure and reduces fertility, ultimately impacting harvest outcomes. Additionally, burning can destroy essential microorganisms needed for plant

growth and increase the risk of soil erosion, all of which contribute to decreased productivity in oil palm plantations.

- 27.0% of them considered air pollution to be the primary issue caused by burning.
- 17.7% of them stated that burning negatively affects land quality, making it less suitable for cultivation.
- 13.5% of them expressed concerns about health risks due to smoke exposure.
- 2.0% of them pointed out the potential for widespread forest fires caused by burning.

Table 3.8. Respondents' Awareness of the Impact of Crop Burning on the Ecosystem

Impact of Crop Burning	Quantity	
	n	%
Impacts on land and forest	4	2.7
Air pollution	40	27.0
Soil quality	26	17.7
Low crop yield	49	33.1
High fertiliser application	3	2.0
Negative effect on health	20	13.5
Creates wildfires	3	2.0
Greenhouse gas emissions	0	0.0
Destroys ecosystems	3	2.0
Total	**148**	**100.0**

n = number of respondents.

Source: Author's analysis, 2025.

These responses indicate an increasing awareness amongst farmers about the environmental and health impacts of poorly managed burning practices. Some respondents suggested that to prevent fires, it is essential to create firebreaks in plantations, helping to contain flames and prevent the spread of fires.

3.4.3.1 Respondents Hopes for Reducing Crop Burning

- 60.0% of respondents believe finding alternatives to burning is a potential solution to the problems it causes.
- 18.6% of respondents believe that utilising crop residues can help balance costs and benefits.

- 21.4% of respondents provided other suggestions (Table 3.9).

Table 3.9. Expectation for Reducing Crop Burning

Expectation to Reduce Crop Burning	Quantity	
	n	%
Reducing slash-and-burn practices	42	60.0
Utilising residues improves cost/benefit balance	13	18.6
Others	15	21.4
Total	**70**	**100.0**

n = number of respondents.

Source: Author's analysis, 2025.

3.4.3.2 Challenges Respondents Face to Adopt Alternative Methods

The biggest concern (73.3%) amongst farmers regarding alternative non-burning methods is additional costs (Table 3.10). Respondents emphasised that providing facilities for skill development and knowledge enhancement should be a top priority to reduce land burning, followed by encouraging research and technological innovation.

Table 3.10. Respondents' Concerns About Reducing Crop Burning

Concern	Quantity	
	N	%
Change from conventional ways	6	7.0
Additional costs for alternative ways to burn crops	63	73.2
Effect on cultivation	17	19.8
Others	0	0.0
Total	**86**	**100.0**

n = number of respondents.

Source: Author's analysis.

Currently, respondents reported that there is no financial support to help farmers shift away from burning practices. A study by Rosyadi (2023) highlighted that independent farmers require substantial funds for replanting. However, the government has actually provided subsidies for replanting under the Director General of Plantations Decree No. 29/KPTS/KB.120/3/2017 on Oil Palm Rejuvenation Guidelines, which grants Rp30 million per hectare to farmers who collaborate with private companies or plasma farmers.

Despite this support, not all farmers are part of plasma schemes or co-operate with private entities, meaning they must cover replanting costs themselves. In the Indonesian oil palm sector, plasma schemes are institutional partnership arrangements between plantation companies and smallholder farmers designed to integrate smallholders into commercial supply chains through the provision of financial support, technical guidance, agricultural inputs, and market access (World Bank, 2011). As a result, only a small number of farmers use heavy machinery for replanting, as they prioritise cost savings while ensuring a continued income from the old oil palm trees being replaced. To manage expenses, many farmers opt for a gradual replanting approach rather than clearing large areas all at once.

3.4.4 Activities to Reduce Crop Burning

Several priorities can be pursued to reduce the land and crop burning in oil palm cultivation that has the potential to harm the environment. The following are key steps that can be taken.

3.4.4.1 Facilitating Skills and Knowledge Building on Alternative Land-Clearing Methods

One of the main challenges in reducing land-burning practices is the limited knowledge amongst farmers about more environmentally friendly land-clearing alternatives. By improving skills and providing proper training, farmers can be introduced to various techniques suitable for their land conditions, such as no-burn methods, agroforestry, or the use of more efficient mechanical technologies. Offering diverse options will allow farmers to adjust their methods according to their capabilities and long-term economic goals.

3.4.4.2 Fostering Research and Technological Innovation

Research and technological innovation must continue to be developed to create more effective solutions for managing oil palm plantations. Technologies that enable land management without burning, such as converting biomass into energy or organic fertilisers, are crucial for further development. Investing in these technologies will not only reduce land burning but also enhance farmers' productivity through more efficient resource utilisation.

3.4.4.3 Promoting Sustainable Agricultural Practices Through Incentive Schemes

The implementation of sustainable agricultural practices should be supported by incentive schemes or subsidies for farmers who adopt environmentally friendly methods. Incentives can take the form of technical assistance, tax relief, or access to green markets. These schemes aim to provide additional motivation for farmers to implement sustainable techniques while ensuring they receive benefits that

match their efforts.

3.4.4.4 Creating Co-Benefits and Prospects for New Markets from Sustainable Agriculture Practices

Developing new market prospects for products derived from sustainable farming practices is a key priority. This can be achieved by expanding markets for green commodities produced without harming the environment or by increasing market demand for oil palm residue-based products, such as biochar or renewable energy from biomass. Opening access to international markets can also add value for local farmers who adhere to sustainability standards.

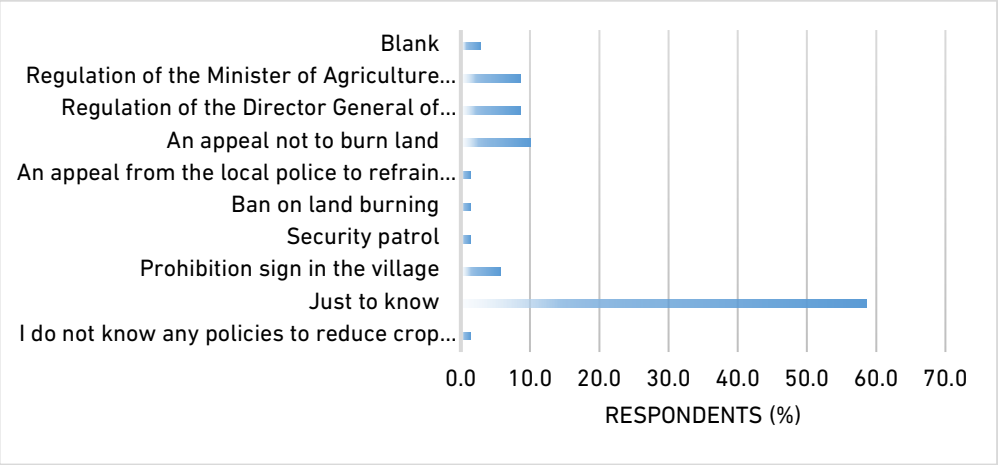
3.4.4.5 Planning for Policy and Regulatory Systems

Policies and regulations regarding land burning have been well implemented, and communities generally comply with these rules. However, there is a need for increased awareness campaigns to ensure a deeper understanding of the existing regulations. More intensive outreach efforts, especially in rural areas, will help prevent accidental or uninformed land-burning practices.

3.4.5 Increasing Knowledge of Crop-Burning Reduction Policies

In general, respondents are aware that burning in oil palm plantations is harmful, particularly because it causes damage to plantation land. They understand that burning is prohibited, but when asked whether they are familiar with the specific regulations that govern this ban, 58.6% stated that they do not know the regulation itself but are aware of the general prohibition. Meanwhile, only 8.6% of respondents reported having knowledge of a formal regulation prohibiting land burning (Figure 3.6).

Figure 3.6. Respondents' Awareness of Policies to Reduce Crop Burning

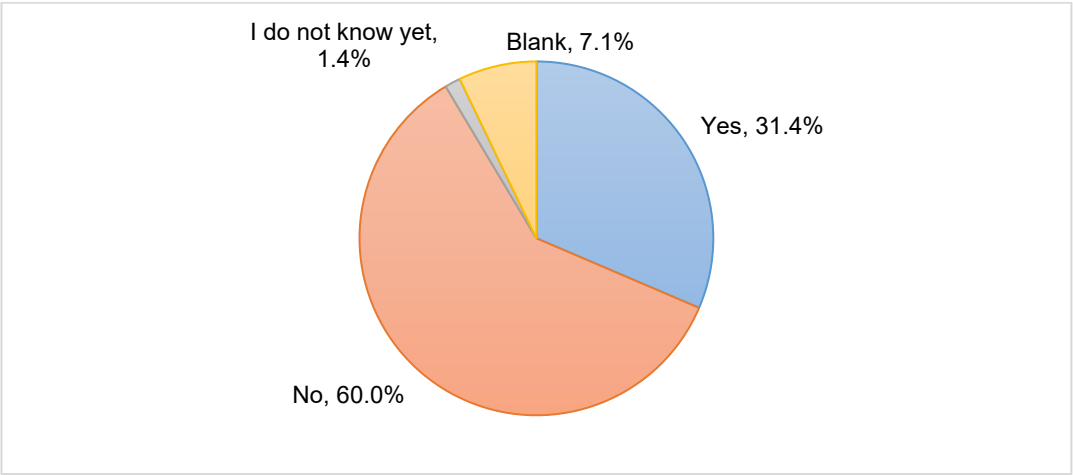


Source: Author's analysis, 2025.

The majority of respondents (58.6%) are only generally aware that there are policies aimed at reducing plant burning but cannot specify any details about these policies. The results also indicate that:

- 10.0% of respondents mentioned a general advisory against land burning.
- 8.6% knew about regulations issued by the Minister of Agriculture and the Director General of Climate Change Control.
- Only 1.4% were aware of policies such as security patrols, formal land-burning bans, or advisories from local law enforcement.
- A small portion of respondents, 1.4%, admitted to having no knowledge of any policies aimed at reducing plant burning.
- 1.4% acknowledged the existence of local regulations that prohibit the burning (band on land burning) of oil palm trunks, with penalties imposed on violators.

Figure 3.7. Respondents' Perceptions of Non-Formal Rules and Local Wisdom to Reduce Crop-Burning Practices



Note: Percentages may not total 100% due to rounding.

Source: Author.

Figure 3.7 illustrates respondents' perceptions regarding the existence of non-formal rules, customary regulations, or local wisdom aimed at reducing crop-burning practices. The majority of respondents (60.0%) stated that such rules or local wisdom were not present in their communities. Meanwhile, 31.4% of respondents acknowledged the existence of non-formal or customary practices related to reducing crop burning. A smaller proportion of respondents left the

question unanswered (7.1%), while only 1.4% indicated that they did not know whether such practices existed.

These findings suggest that formal or informal community-based mechanisms for controlling crop burning may not yet be widely recognized or consistently implemented across the surveyed areas. The relatively low proportion of affirmative responses may also indicate varying levels of awareness, local institutional capacity, or the decline of traditional environmental management practices within rural communities.

3.4.5.1 Respondents' Actions to Prevent Plant Burning

In response to the negative effects of plant burning, most farmers have taken preventive measures by avoiding indiscriminate burning. They are committed to not burning oil palm land and prefer alternative, more environmentally friendly methods.

When burning is unavoidable for crop residue management, farmers take precautions, such as creating firebreaks to prevent flames from spreading to other crops or lands. This reflects their efforts to promote sustainability and environmental health, and most respondents support the existing policies.

3.4.5.2 Priorities to Implement to Reduce Plant Burning

Several key priorities can be pursued to reduce land and plant burning in oil palm cultivation, particularly in ways that prevent environmental damage.

3.4.5.2.1 Enhancing Skills and Knowledge of Alternative Land-Clearing Methods

One of the biggest challenges to reduce land-burning practices is the lack of knowledge amongst farmers regarding alternative, environmentally friendly, land-clearing techniques.

By providing training and skill development programmes, farmers can be introduced to various suitable techniques, such as zero-burning methods, agroforestry, more efficient mechanical technologies.

By offering diverse options, farmers can adjust their methods based on their capabilities and long-term economic goals.

3.4.5.2.2 Strengthening Policy and Regulation Systems

Policies and regulations regarding land burning have been well implemented, and most farmers tend to comply with the rules. However, there is a need for more intensive public outreach to ensure a deeper understanding of existing regulations.

Better outreach, especially in rural areas, can help prevent accidental burning due to lack of awareness.

3.4.5.2.3 Promoting Sustainable Farming Through Incentive Schemes

Sustainable agricultural practices should be supported through incentives or subsidies for farmers who adopt eco-friendly methods. Incentives could include technical assistance, tax relief, or access to green markets. This approach provides additional motivation for farmers to apply sustainable techniques, ensuring they gain comparable financial benefits from their efforts.

3.4.5.2.4 Encouraging Research and Technological Innovation

Research and technological advancements must continue to develop more effective solutions for oil palm land management. Non-burning residue management technologies — such as biomass processing for energy or organic fertilisers — are crucial for future development. Investing in these technologies will not only reduce land burning but also enhance farmers' productivity through more efficient resource utilisation.

3.4.5.2.5 Creating New Market Prospects

Finally, developing new market opportunities for products derived from sustainable farming practices is a key priority.

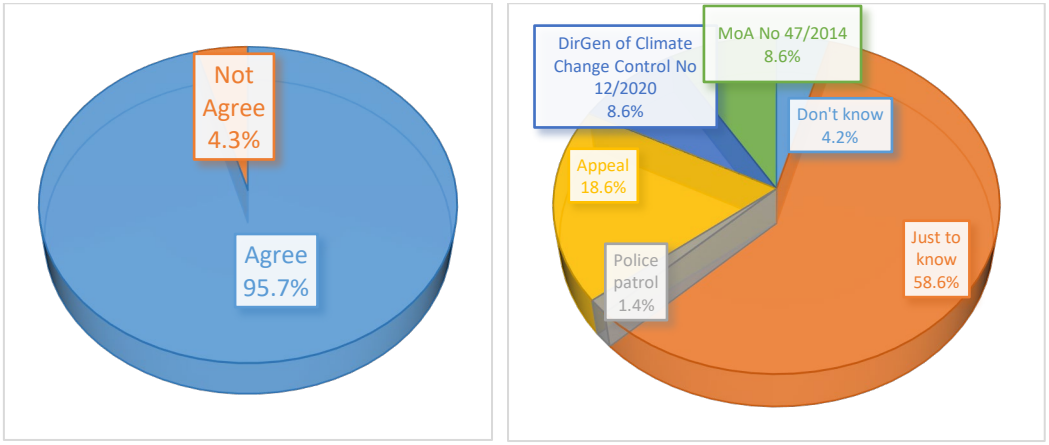
This can be achieved by expanding green commodity markets for eco-friendly products, increasing demand for oil palm residue-based products, such as biochar or renewable energy from biomass, opening access to international markets, which can add value for local farmers implementing sustainability standards.

By implementing these strategies, farmers can reduce their reliance on burning, minimise environmental harm, and benefit from sustainable and profitable agricultural practices.

3.4.5.3 Respondents' Awareness of Policies to Reduce Crop Burning

The vast majority of respondents (95.7%) know that burning practices in oil palm plantations are not good, especially as they will cause damage to plantation land. However, awareness of the regulations is lower; 58.6% of respondents stated they do not know the rules in detail but are only generally aware of them (Figure 3.8).

Figure 3.8. Information about Policies to Reduce Crop Burning



DirGen = Director General, MoA = Memorandum of Understanding.

Note: Percentages may not total 100% due to rounding.

Source: Author.

Approximately 8.9% of respondents were aware of policies aimed at reducing land and plantation burning in Indonesia, including the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 47 of 2014 concerning the establishment of fire brigades and the implementation guidelines for the prevention and control of land and plantation fires. In addition, a further 8.9% of respondents were also familiar with Regulation of the Director General of Climate Change Control No. 12 of 2020, which stipulates the standard operating procedures for forest and land fire control activities. These regulations are designed to provide technical and procedural guidelines for preventing and managing land fires, which are often one of the main causes of ecosystem damage and air quality deterioration.

In practice, these regulations are implemented through preventive measures, such as, public advisories and installation of announcement boards in village offices to inform communities about the land-burning ban, informal regulations established through mutual agreements amongst community members at the village, neighbourhood (Rukun Warga), and sub-neighbourhood (Rukun Tetangga) levels. These local agreements are generally better accepted by the community, as they involve local participation and collaboration, and farmers' perspectives on plant burning reduction policies.

Despite the existence of a formal regulatory framework under the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 47 of 2014, the implementation of fire prevention and control measures at the community level remains uneven, particularly amongst smallholder oil palm farmers. Empirical studies on oil palm cultivation indicate that land clearing through burning persists

largely due to limited regulatory awareness, high upfront costs of non-burning alternatives, and restricted access to appropriate technologies and extension services (Carmenta et al., 2017; Purnomo et al., 2020).

In addition, weak enforcement mechanisms at the local level and inconsistent alignment between national regulations and village-level governance further constrain effective compliance (Tacconi et al., 2016). For smallholders, traditional burning practices are often perceived as the most affordable and least risky option in the context of uncertain yields and market volatility in the oil palm sector (Gaveau et al., 2016; Santika et al., 2022). Consequently, the regulation has not yet functioned as an effective behavioural change instrument, underscoring the need to strengthen capacity building and targeted incentives, and improve integration of fire prevention policies into smallholder oil palm support systems.

Although the Regulation of the Director General of Climate Change Control No. 12 of 2020 provides comprehensive operational guidelines for forest and land fire control, its implementation at the community level remains limited. The regulation is largely applied through institutional fire management mechanisms rather than embedded within smallholder agricultural practices. Limited farmer awareness, weak integration with extension services, and a focus on reactive fire response reduce its effectiveness in preventing burning amongst smallholder oil palm farmers.

3.4.5.3.1 Respondents' Perspectives on Plant Burning Reduction Policies

According to the survey results, the vast majority of farmers (93.0%) express support for policies that prohibit or reduce plant burning. This high level of agreement suggests a generally positive attitude toward fire prevention measures and an acknowledgement of the environmental and agronomic damage caused by burning practices. However, a smaller proportion of farmers (7.0%) indicate only partial agreement with these policies, emphasising the need for more intensive outreach and continuous education.

Farmers who express partial agreement argue that limited understanding of the regulatory framework constrains effective compliance. Previous studies have shown that farmers' acceptance of fire-related regulations is strongly influenced by their level of awareness, access to information, and engagement in extension programmes (Carmenta et al., 2017; Purnomo et al., 2020). Without adequate explanation of the objectives, procedures, and long-term benefits of burning restrictions, regulations are often perceived as punitive rather than supportive.

Empirical evidence further indicates that education, participatory training, and regular monitoring play a critical role in translating policy acceptance into behavioural change amongst smallholder farmers (Tacconi et al., 2016; Santika et

al., 2022). When farmers are equipped with practical knowledge of alternative land preparation methods and supported through extension services, compliance with land-burning bans tends to improve. Consequently, strengthening capacity building and monitoring mechanisms is expected to significantly reduce land-burning practices, thereby contributing to environmental protection and climate change mitigation efforts.

3.4.5.3.2 Respondents' Commitment to Preventing Plant Burning

As a response to the problems caused by plant burning, most farmers have already taken preventive measures by avoiding indiscriminate burning. They commit to not burning crop reside on oil palm plantations and prefer more environmentally friendly alternatives. In cases where burning is unavoidable for crop residue management, farmers exercise caution, by, for example, creating firebreaks to prevent the spread of flames to other plants or lands. This approach demonstrates their efforts to maintain sustainability and protect the environment. Similar risk-mitigation behaviours amongst smallholders have been documented in previous studies, indicating growing awareness of the environmental and agronomic impacts of burning (Ketterings et al., 1999; Carmenta et al., 2021).

Survey results further show that an overwhelming majority of farmers (97.0%) support existing policies to prevent or reduce plant burning. This strong endorsement suggests that challenges to implementation are less related to farmer resistance than to practical constraints, reinforcing the need for continued extension support, access to non-burning technologies, and strengthened community-based fire prevention mechanisms (Jelsma, 2017; Sofiyuddin et al., 2021).

3.4.5.3.3 Challenges to Boost Capacity Building and Knowledge-Sharing

In general, respondents have limited awareness of opportunities for capacity development and knowledge-sharing to support a reduction in plant burning. However, farmers face challenges to implement these initiatives on the ground due to several factors. Limited knowledge and access to information are key factors. Some farmers may not be aware of alternatives to plant burning or understand the long-term benefits of more sustainable practices (Veronica et al., 2018). In addition, not all farmers have easy access to training, technology, or the resources needed to implement new methods. Remote geographical locations often pose a challenge (Astiti, Falatehan, and dan Putri, 2022). Cost is also an issue. While sustainable farming methods can save money in the long run, the initial investment in tools or new technology can be a financial burden for farmers.

Other challenges identified include:

- Risk and uncertainty. Farmers often face risks such as unpredictable weather

and fluctuating market prices. Adopting new practices can be seen as risky if outcomes are uncertain (Helmi and Sasaoka, 2018).

- Tradition and habits. Farming practices passed down for generations can be difficult to change. Sometimes, traditional methods persist simply because they are deeply rooted in local agricultural culture (Aminah, 2015).
- Support and policies. Lack of government support or policies that do not actively encourage sustainable practices can also be a barrier for farmers (Astiti, Falatehan, and dan Putri, 2022).

3.4.5.3.4 Addressing the Challenges

To overcome these challenges, collaboration between farmers, agricultural extension officers, government bodies, and NGOs is crucial. By providing education, resources, and necessary support, more farmers can be encouraged to adopt sustainable agricultural practices.

Most respondents have limited knowledge of capacity building opportunities and knowledge-sharing initiatives for reducing plant burning. However, the government has implemented capacity development programmes in peatland areas through the Peatland Restoration Agency. This agency conducts several key activities, including:

- Peatland ecosystem restoration. Conducting rewetting (peatland rehydration) through canal blocking, bore wells, and other efforts to prevent fires.
- Mangrove rehabilitation. Replanting mangroves in degraded coastal areas to prevent erosion, saltwater intrusion, and increase biodiversity.
- Empowering local communities. Training and economically empowering communities through environmentally friendly activities, such as sustainable agriculture or local product development.
- Forest and land fire prevention. Conducting awareness campaigns and fire mitigation training, especially in fire-prone peatland areas.
- Monitoring and evaluation. Implementing surveillance and assessment of restoration programmes using technology such as drones and satellite monitoring.

These initiatives aim to preserve these critical ecosystems for the sustainability of the environment and the livelihoods of local communities.

3.4.6 Capacity Building and Knowledge-Sharing

Several opportunities can enhance capacity building and knowledge-sharing to reduce practices for crop residue and cleared vegetation in oil palm cultivation.

Some key priorities include:

- Bridging the knowledge gap. Most respondents chose this as their first priority. One of the main challenges in reducing land burning is the knowledge gap amongst stakeholders, especially farmers and local communities. To bridge this gap, more intensive training and education must be provided. Extension programmes targeting smallholder farmers, either through face-to-face meetings or digital platforms, can help them understand more sustainable alternatives to land clearing without burning.
- Learning from peers. This action was the second priority for respondents. One effective way to share knowledge is through peer learning. Farmers who have successfully implemented no-burn farming techniques can serve as role models for other farmers. Through this approach, relevant knowledge and practical experience can be disseminated more quickly and better received because the source of information comes from fellow farmers who are facing similar challenges.
- Investing in the future. It is important to shift the short-term paradigm that often only focuses on immediate results, towards an approach that is more oriented towards long-term sustainability. Investments in training, technology, and policies that support sustainable agriculture will not only have positive environmental outcomes, but will also improve farmers' productivity and well-being in the long term. The government and the private sector need to play an active role in providing funding for these initiatives. Investing in the future is the third priority according to respondents.
- Spreading awareness beyond the farm (environmental impacts). This component is the fourth priority for respondents. In addition to providing technical knowledge, it is important to raise public awareness, especially outside the agricultural sector, about the environmental impacts of land burning. This socialisation should include issues such as air pollution, loss of biodiversity, and the impacts of climate change due to forest fires. By expanding understanding of these impacts, it is hoped that more parties will be actively involved in maintaining environmental sustainability.
- Leveraging local knowledge/wisdom. The fifth priority for respondents is leveraging local wisdom, which is an important opportunity that is often overlooked. Indigenous peoples and local communities have traditional knowledge and practices that have been proven to be environmentally friendly and sustainable for many years. By integrating these practices into modern land management strategies, not only will sustainability be

strengthened, but it will also strengthen the cultural and social identity of local communities.

Empowering innovation. Innovation is key to finding more effective solutions to reduce land burning. Empowering innovation was chosen by respondents as the last priority. Programmes that empower farmers to innovate in utilising oil palm residues or other environmentally friendly technologies should be encouraged. In addition, collaboration with research institutions and the private sector is also important to create new technologies that can be accessed and applied by smallholder farmers.

3.4.7 Involving Stakeholders in Sustainable Oil Palm Cultivation

Currently, only a few farmers understand the importance of stakeholder involvement in the development of sustainable oil palm cultivation. Data shows a significant gap between farmers who are aware of stakeholder involvement and those who expect stronger collaboration in this sector. For example, 49% of farmers recognise the role of stakeholders, yet 58% of them express the need for co-operative initiatives to support their farming activities.

Amongst stakeholders, individual farmers or farmer groups are the primary actors directly involved in agricultural activities and land management. However, only 36% of them are aware of the importance of agricultural extension service providers, despite 82% of farmers hoping for training programmes and demonstration sites to help improve their productivity.

In addition, research institutions that develop environmentally friendly technologies to reduce plant-burning practices also play a crucial role. Although only 11% of farmers are aware of these institutions, 78% of them express interest in collaborating with them. Government agencies also play a role in establishing regulatory frameworks to support sustainable farming practices, yet only 20% of farmers are aware of this role, while 64% expect clearer collaboration with the government.

Another key player in reducing land-burning practices is the private sector and business community. While only a few farmers understand the role of this sector, they hope for government incentives to promote environmentally friendly land clearing methods, as well as disincentives for forest-burning practices. Only 9% of farmers are aware of the private sector and business community's role in utilising technology and market development to support the reduction of plant-burning practices, while 80% expect greater contributions from these sectors.

The role of civil society groups, NGOs, and local communities is also expected to

raise awareness and promote sustainable agricultural practices. Only 13% of farmers acknowledge their contributions, yet 82% expect more intensive collaboration with them. Additionally, 27% of farmers are aware of incentives for environmentally friendly land clearing and disincentives for forest burning in oil palm expansion, while 80% hope for more structured incentive and disincentive policies.

These findings highlight a gap between farmers' awareness of stakeholders' roles in sustainable oil palm cultivation and their expectations for greater collaboration to support environmentally friendly farming practices.

3.4.8 Priority Programmes to Reduce Crop and Land Burning

The following are priority programmes to increase involvement in reducing crop and land burning for oil palm plantations:

- Farmer-to-farmer exchange. This aims to facilitate the transfer of knowledge and experience between farmers. Through this programme, farmers can learn from each other about techniques and best practices that have been successfully implemented by their colleagues, thereby reducing dependence on burning methods.
- Market access to sustainable products and services. This is another important priority for farmers. They hope to reach a wider market for environmentally friendly agricultural products, which not only provide economic value but also raise awareness of the importance of sustainable agricultural practices.
- Better technology transfer and adaptation. When farmers are given access to innovations and tools, it can help them to cultivate without burning land.
- A joint law enforcement strategy. This is needed to ensure that all parties comply with existing regulations, so that an environment is created that is conducive to better agricultural practices.
- Online learning centres. Such centres can be a very useful solution to provide access to information and education for farmers. By leveraging digital technology, farmers can gain the latest knowledge on sustainable farming practices without having to leave their land.
- Public–private partnerships. These partnerships allow collaboration between the government, the private sector, and farmers and can produce effective programmes to reduce burning. Through this partnership, it is hoped that investment in infrastructure and technology that supports sustainable

agriculture will emerge.

- Financial incentive mechanisms. Financial incentives need to be introduced to encourage farmers to switch from burning practices. These incentives can be in the form of subsidies, technical assistance, or award programmes for farmers who successfully implement environmentally friendly farming practices.

By implementing these priority programmes, it is hoped that farmer involvement in reducing crop and land burning can increase, thereby creating a positive impact on the environment and the sustainability of the agricultural sector.

There are several integrated strategy priorities to encourage the reduction of crop and land burning in oil palm cultivation:

- Promoting sustainable agricultural practices. The use of environmentally friendly and sustainable agricultural techniques should be a primary focus, such as the use of land clearing methods without burning, wise management of crop residues, and the implementation of agroforestry practices that support ecosystem balance.
- Research and development. Continuous research must continue to be encouraged to develop new technologies and innovations that can be applied in the field.
- Providing incentives and support for sustainable agricultural practices. Farmers need real incentives to switch from land-burning practices to more environmentally friendly methods, such as subsidies for modern agricultural technology, financial assistance for processing residues without burning, to providing awards or certification for farmers who successfully implement sustainable agricultural practices.
- Stakeholder engagement and awareness. Increasing awareness at all levels about the negative impacts of land burning on the environment and human health can encourage behavioural change.
- Market access to new products and services. Developing markets for environmentally friendly commodities or products based on oil palm residues, such as biochar or renewable energy, can add value to farmers and encourage them to adopt better methods.
- Policy and regulation. Governments should strengthen law enforcement and impose strict sanctions for violations, while still providing guidance to smallholders who may not have access to alternative technologies.

3.4.9 Technology to Reduce Crop Burning and Use Oil Palm Residues

Various technologies have been implemented and are expected to be further developed to reduce plant-burning practices and utilise oil palm residues more efficiently. Data indicates a significant gap between farmers who are aware of available technologies and those who hope for wider implementation. One widely used technology is land clearing using heavy machinery; however, this method damages the humus layer of oil palm soil.

Table 3.11. Gap between Farmers' Awareness of Available Technologies and their Expectation for Implementation

Know (%)	Expect (%)	Technologies
24.3	77.1	Machinery instalment on farmland
8.6	71.4	System for collecting residues
14.3	70.0	Scheme to valorise residues
41.4	54.3	Removal of residues from farmland surface without burning
5.7	4.3	Others

Source: Author's analysis.

One of the technologies recognised by 24.3% of farmers is instalment-based agricultural machinery, which 77.1% of farmers hope to adopt to facilitate land management without burning crop residues. This technology enables the use of machinery to process crop residues more quickly and efficiently, thereby reducing fire risks and improving soil quality.

Another known technology is the residue collection system, recognised by 8.6% of farmers, while 71.4% express a desire for broader implementation. This system is designed to collect crop residues, such as stems and leaves left after harvest, so they can be processed or repurposed into products like compost or bioenergy biomass.

Additionally, there is a residue valorisation scheme, known by 14.3% of farmers but desired by 70.0% of them. This technology allows for the utilisation of oil palm residues by adding value, such as converting them into biochar or organic fertilisers. This approach transforms waste materials that would otherwise be discarded or burned into useful products, thereby increasing efficiency and sustainability in agricultural practices.

Another highly anticipated technology, desired by 54.3% of farmers, is a method for

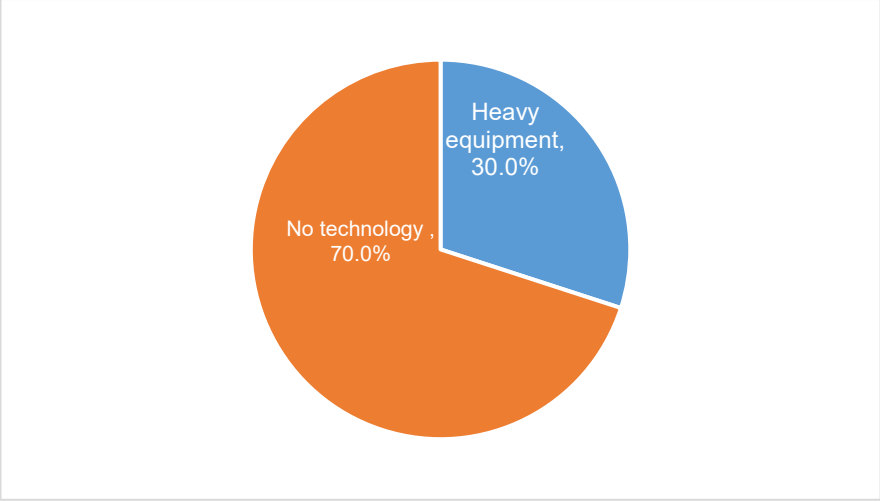
removing crop residues from farmland without burning. However, only 41.4% of farmers are aware of this technology despite the high demand, as it can significant environmental impacts, such as air pollution and soil degradation caused by burning. This method includes mechanical or biological processing of crop residues and conservation-based agricultural practices that are more environmentally friendly.

Last, alternative technologies remain largely unknown amongst farmers. Although only 5.7% of farmers mention other technologies, there is still significant room for innovation and technological advancements in this field. Further research and support from various stakeholders, including government and the private sector, are needed to identify practical and sustainable solutions for addressing plant-burning issues and optimising oil palm residue utilisation (Table 3.11).

3.4.9.1 Impact of Land-Clearing Technologies

One commonly implemented method of oil palm land clearing is the use of heavy machinery (30.0%), but this damages soil humus and can affect soil fertility. While heavy equipment has been used to manage plant waste, the majority of respondents (70.0%) state that no specific technology has been implemented to handle plant waste, and only 30.0% report the use of heavy machinery. Moreover, 70.0% of respondents also believe that no significant effects have resulted from using technology for plant waste management (Figure 3.9).

Figure 3.9. Respondents' Use of New Technology



Note: Percentages may not total 100% due to rounding.
Source: Author.

The use of heavy machinery in oil palm land clearing has been shown to accelerate residue removal and reduce reliance on burning; however, several studies highlight its potential negative impacts on soil quality. Intensive mechanisation can disrupt soil structure, reduce soil organic matter and humus content, and increase compaction, which may ultimately affect soil fertility and long-term productivity (Lal, 2001; Hamza and Anderson, 2005). These trade-offs may explain farmers' reluctance to adopt mechanised land-clearing technologies.

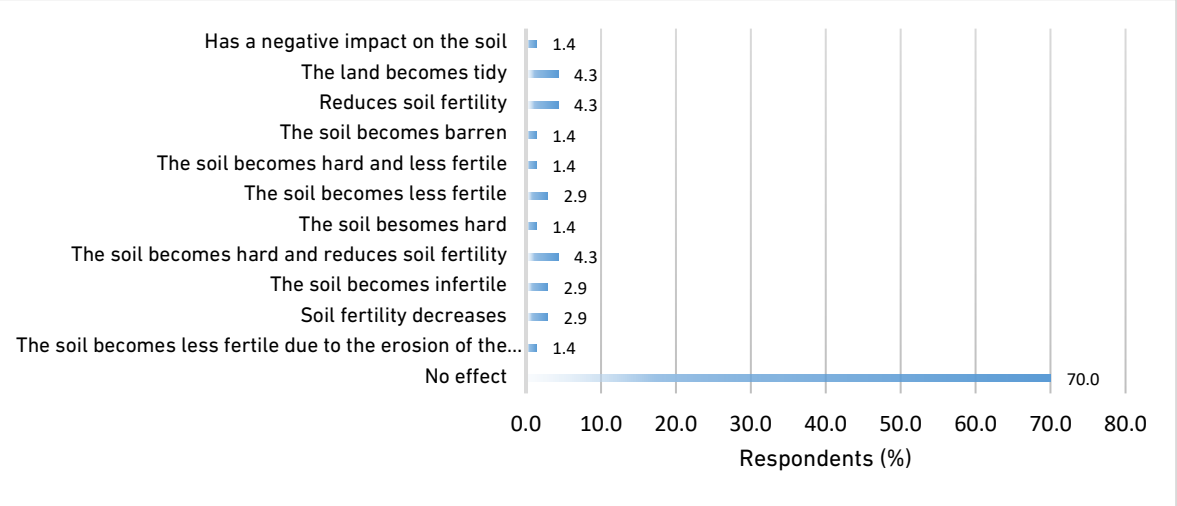
Consistent with this interpretation, 70.0% of respondents perceive that the use of technology for plant waste management has not resulted in significant benefits (Table 3.9; Figure 3.10). Previous research suggests that the perceived limited impact of mechanisation often arises when technologies are not accompanied by appropriate soil management practices, training, or follow-up support (Bessou et al., 2017; Sofiyuddin et al., 2021). Without adequate guidance, farmers may not observe immediate productivity gains, reinforcing the perception that such technologies offer little advantage.

Overall, these findings indicate that while mechanised land clearing presents an alternative to burning, its adoption and effectiveness depend heavily on complementary practices, farmer training, and context-specific implementation. Strengthening extension services and promoting sustainable mechanisation approaches are therefore essential to enhance the positive impacts of land-clearing technologies while minimising soil degradation.

3.4.9.2 Strategies to Raise Awareness and Promote Adoption of Alternatives to Crop Burning

Around 36% of respondents recommend that initiatives aimed at raising awareness about the importance of reducing plant burning should be intensified. Local and national awareness campaigns can help educate communities on the negative environmental and health impacts of land burning. This would encourage farmers to consider alternative technologies that prevent burning while also providing long-term agricultural sustainability benefits.

Figure 3.10. Respondents' Perceived Benefits from the Technology Used



Source: Author's analysis, 2025.

To enhance participation, respondents suggest that collaborative programmes amongst farmers, including knowledge exchange visits, should be prioritised. Thus, promoting sustainable agricultural practices should be a key strategy in reducing crop residue burning.

Another crucial strategy is providing financial incentives to support sustainable farming practices. The biggest concern amongst farmers regarding the adoption of alternative methods is the additional cost. This is supported by data showing that 70.0% of respondents state that no technology has been implemented, while 30.0% report using heavy machinery to manage plant waste (Figure 3.9).

By addressing cost concerns and increasing technology adoption, it is hoped that the reduction of plant-burning practices can be achieved more effectively and sustainably.

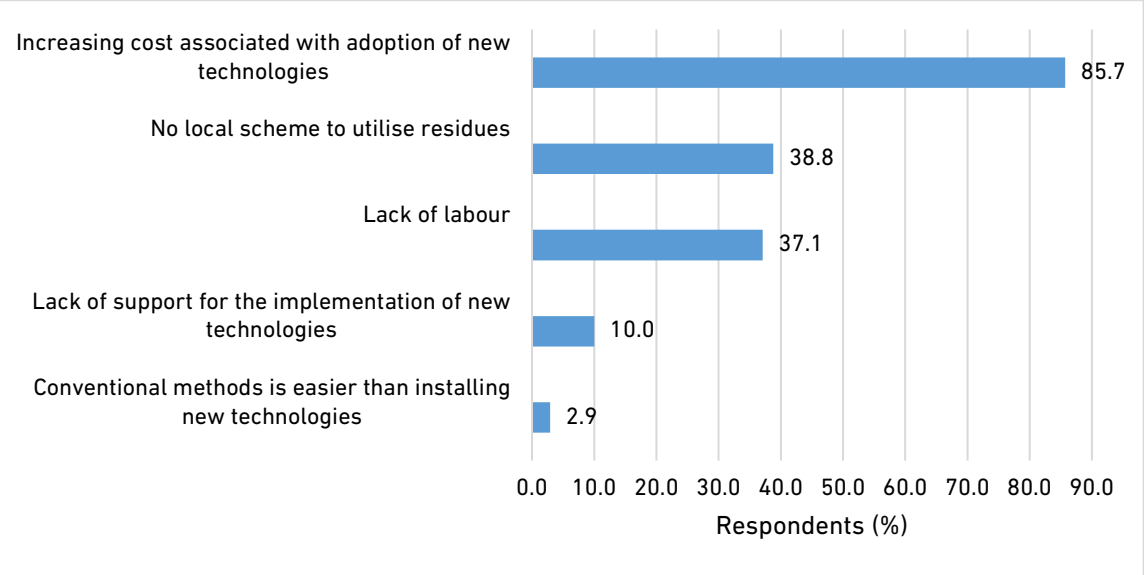
3.4.9.3 Barriers to Implementing Technology to Reduce Crop Burning

In this section, respondents were allowed to select more than one barrier to implementing technologies aimed at reducing palm oil crop burning. Consequently, the barriers presented in Figure 3.11 are not mutually exclusive and reflect the complexity of challenges faced by farmers.

The adoption of new technologies to reduce crop and land burning in oil palm cultivation faces several significant barriers. The main barrier faced by farmers and stakeholders is the increasing costs associated with adopting new technologies. As many as 85.7% of them assessed that new technologies require

large initial investment costs, which discourages many farmers, especially smallholders, from switching from traditional methods. These high costs include the purchase of equipment, training, and maintenance of the technology, all of which add to their financial burden.

Figure 3.11. Respondents' Barriers to Implementing Technology



Source: Author's analysis, 2025.

Another barrier is no local scheme to utilise residues, 38.8%. This is because in the region there is no adequate local scheme or system to utilise plantation or forest residues (such as trunks, leaves, or other organic waste) in a useful way. New technologies can often be used to process these residues into more useful products, such as bioenergy, compost, or other raw materials, while preventing practices such as open burning.

Without local schemes or initiatives, these residues may not be managed properly, which can be one of the causes of forest or plantation fires, either because they are burned directly or because they become natural fuel for the fire to spread. Technology-based solutions, if supported by local policies and implementation, can help significantly reduce these risks.

Next is lack of labour, especially in the implementation of new technologies. This is because it requires knowledge and expertise in using it. It was chosen by 37.1% of respondents.

Lack of support for the implementation of new technologies is also a significant barrier, with 10.0% of respondents stating that they felt they did not receive

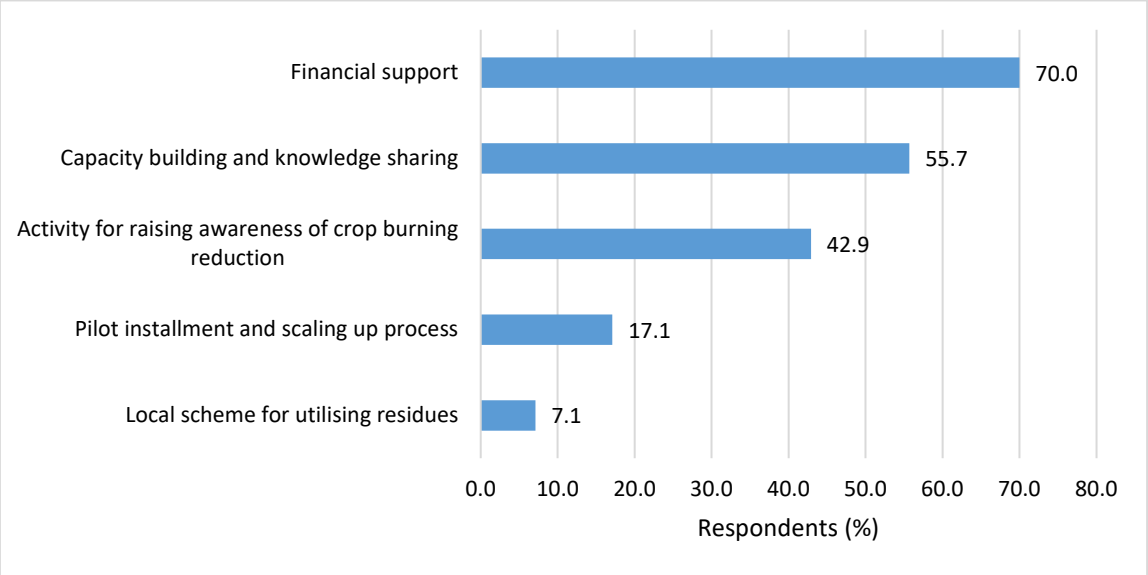
adequate assistance in terms of access to technology, training, or necessary subsidies. This lack of support further complicates farmers' efforts to adapt to new, more environmentally friendly technologies, especially in remote areas with minimal infrastructure and access to information. In addition, 2.9% of respondents considered using conventional methods easier than installing new technologies.

To overcome these challenges, several potential solutions can be implemented (Figure 3.12), including:

- Financial support. A total of 70.0% of respondents indicated that financial support, such as government subsidies, low-interest credit, or tax incentives, would be highly beneficial in encouraging the adoption of new technologies. With financial assistance, farmers would be better equipped to cover high initial costs, enabling them to adopt new technologies without adding financial strain.
- Capacity building and knowledge-sharing. Another solution is capacity building through training programmes and knowledge-sharing initiatives, which 55.7% of respondents consider essential. These programmes can provide farmers with a better understanding of how to effectively use new technologies while also helping them address concerns about potential yield reductions. Continuous agricultural extension services and experience-sharing amongst farmers who have successfully adopted new technologies can further accelerate adoption.

- Activities for raising awareness of crop-burning reduction. Activities for raising awareness of crop-burning reduction are initiatives aimed at educating communities, particularly farmers, about the negative impacts of land and crop residue burning. These efforts focus on the environmental and health consequences of crop burning, promoting alternative, sustainable farming practices, and encouraging behavioural change to reduce dependence on burning methods. Approximately 42.9% of respondents identified this option as a potential solution.

Figure 3.12. Respondents' Solutions to be Implemented Alongside the Technology



Source: Author's analysis, 2025.

3.4.9.4 Activities to Raise Awareness of Methods to Reduce Crop Burning

Activities to raise awareness of ways to reduce crop burning can include educational campaigns, training sessions, seminars, or extension programmes that provide information on:

- Dangers of land burning. For example, they could explain its impact on health, environmental damage, and contribution to climate change.
- Alternatives to burning. Solutions such as using crop residues for organic fertilisers, livestock feed, or bioenergy production could be explored.
- Benefits of method changes. This could provide insights into how sustainable residue management practices can improve soil quality and long-term crop yields.

The primary goal is to encourage behavioural change by raising awareness about the importance of abandoning burning practices and adopting more environmentally friendly methods. These initiatives typically involve government agencies, NGOs, local communities, and the private sector.

3.4.10 Discussion

A study conducted in Tebo Regency, Jambi Province, and Sanggau Regency, West Kalimantan Province, found that most respondents work as farmers, with a small percentage engaged in entrepreneurship, teaching, and law enforcement. Male

respondents dominate the sample, accounting for over 97%, while female respondents make up only 2.9%. Most farmers fall within the 40–49 age group, followed by the 30–39 age group, while the number of young farmers remains low, reflecting the declining interest of younger generations in agriculture.

In terms of education, most farmers are junior or senior high school graduates, which can be a valuable asset for adopting more modern and sustainable agricultural practices. The majority have 11–20 years of experience, demonstrating a high level of expertise and maturity in their profession.

Most farmers rely on agriculture as their primary source of income, indicating a strong dependence on this sector. However, many are not members of farmer groups, which can limit their bargaining power and competitiveness. Existing farmer groups often do not function effectively due to limited institutional capacity, low access to capital, technology, information, and markets, as well as infrastructure constraints. Additionally, innovation in agriculture remains underutilised due to inadequate resources, such as technology and financial support. Farmers generally own small plots of land (mostly under 5 hectares), which can affect their production capacity and income.

3.4.10.1 Land Clearing Challenges for Oil Palm Plantations

Land clearing for oil palm plantations remains a concern, particularly regarding the use of burning methods by a small number of farmers. However, most farmers in both study locations do not practice burning, demonstrating a high level of awareness of environmental conservation.

Indonesia's 'zero-burning' policy, implemented since 2014, has significantly reduced land-burning practices. However, this policy poses challenges for small-scale farmers, who must find alternative methods to dispose of crop residues that are often more expensive and time-consuming. Farmers have adopted various land management techniques, such as felling and intercropping oil palms with rubber trees.

Other studies, such as those by Astiti, Falatehan, and dan Putri (2022) and Rosyadi (2023), show that replanting is often done gradually using chainsaws to optimise planting rotation and cost efficiency. Heavy machinery for replanting remains limited to farmers with larger land areas due to high costs. Research by Safitri et al. (2024) highlights the negative impact of land burning on soil fertility and palm oil productivity.

Farmers in this study also expressed concerns about air pollution, land quality, and health impacts from burning smoke. While awareness of the environmental and

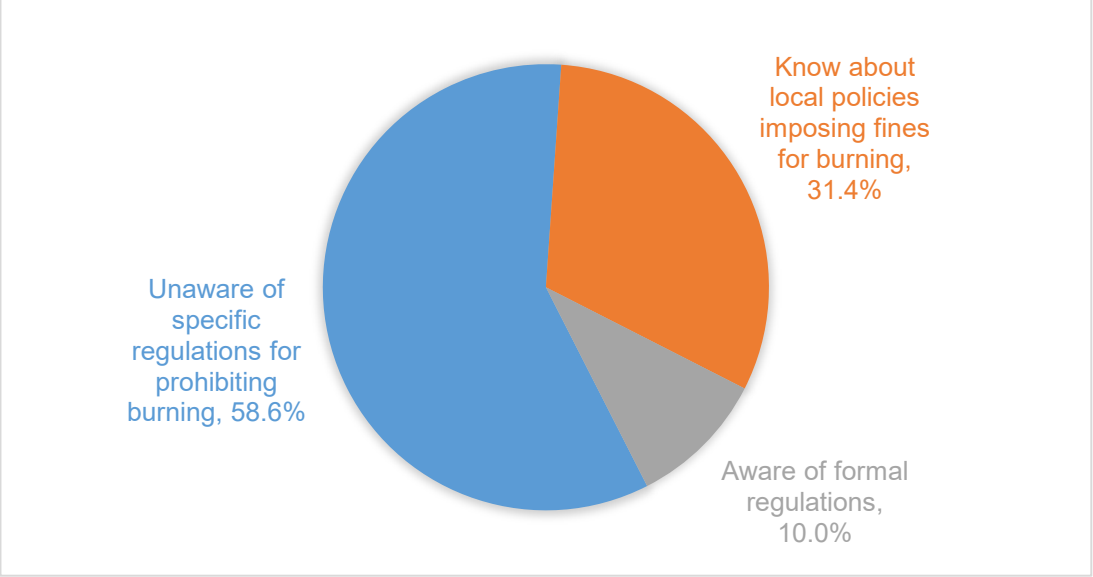
health effects of land burning has increased, the biggest concern remains the additional costs of alternative methods. Therefore, financial support, skill development, and knowledge-sharing programmes are top priorities for reducing crop burning.

The Government of Indonesia has provided subsidies for replanting, but implementation remains challenging, particularly for independent farmers who do not collaborate with private companies or participate in plasma schemes.

3.4.10.2 Respondents' Awareness of Regulations and Compliance

While most respondents acknowledge that burning oil palms on plantations damages the land, 58.6% were unaware of specific regulations prohibiting burning. Only 9% were aware of formal regulations, while 31.4% knew about local policies imposing fines for burning, as seen in Figure 3.13.

Figure 3.13. Respondents' Awareness of Regulations on Oil Palm Burning



Note: Percentages may not total 100% due to rounding.
Source: Author's analysis.

Most farmers have already adopted more environmentally friendly alternatives, such as creating fire barriers when burning is unavoidable. This commitment reflects efforts to ensure environmental sustainability and awareness of the negative effects of land burning.

Indonesia's policies on reducing crop burning, such as the Minister of Agriculture Regulation No. 47/2014 and Director General of Climate Change Control Regulation No. 12/2020, aim to prevent and control land fires that harm ecosystems and air

quality. Implementation includes preventive measures such as public announcements and community agreements at the village level.

Under the Job Creation Law, Article 69 paragraph (1) (h) prohibits clearing land through burning practices. However, paragraph (2) provides an exception for communities that carry out such practices in accordance with local wisdom and traditional customs in their respective regions.

At the provincial level, West Kalimantan has issued a government policy through Governor's Regulation (Pergub) Number 103 of 2020 on Clearing Agricultural Land Areas Based on Local Wisdom which permits people to clear land by burning.

Figure 3.14. People Fighting Fire

Source: Antara News, 2015.

The reality on the ground is sometimes different from the ideal. One community had jointly burned the land. This action had a direct, detrimental community impact. Eventually the police became involved and came to the site to investigate the incident. As a result, the community was prohibited from burning the land for a fixed period of time (Figures 3.14 and 3.15).

Although 93% of farmers support the ban or reduction of crop burning, only 9% are specifically aware of the regulations. Further education and monitoring are needed to ensure effective policy enforcement, support environmental protection, and mitigate climate change.

Surveys indicate that general awareness of the burning ban stands at 59%, with

most farmers committed to avoiding indiscriminate burning and adopting more environmentally friendly methods.

Figure 3.15. Sanctions for Crop Burning in the Field

Source: Author.

3.4.10.3 Challenges to Reduce Crop Burning

The key barriers to reducing crop burning include limited knowledge and limited access, including to financial resources, agricultural machinery, and technical information, as well as high costs, perceived risks, traditional practices, and insufficient policy support (Veronica et al., 2018; Astiti, Falatehan, and dan Putri, 2022; Helmi and Sasaoka, 2018; Aminah, 2015). Collaboration between farmers, agricultural extension workers, government agencies, and NGOs is crucial. Intensive training, peer learning, and investments in sustainable technologies can help farmers understand and adopt alternatives to land burning.

Increasing environmental awareness and leveraging local wisdom are also important for sustainability. Government and private sector incentives must be strengthened to motivate farmers to adopt eco-friendly farming practices, enhance productivity, and improve their long-term welfare (Veronica et al., 2018; Safitri et al., 2024).

3.4.10.4 Stakeholder Roles in Sustainable Oil Palm Development

An analysis of stakeholder roles reveals gaps between farmers' knowledge and their expectations regarding stakeholder involvement. Respondents reported that

- only 36% of farmers recognise the importance of extension service providers, yet 82% expect training programmes; and
- only 11% understand the role of research institutions, but 78% hope for collaboration with them.

This highlights the need for more intensive socialisation and awareness-raising efforts regarding stakeholders' roles in supporting sustainable agriculture. Studies by Goh et al. (2016) and Obidzinski et al. (2012) emphasised that effective stakeholder involvement enhances the success of sustainable agricultural practices. Collaboration between governments, the private sector, and communities is vital for addressing environmental challenges in the palm oil industry.

Priority programmes such as market access, technology transfer, public–private partnerships, financial incentives, and law enforcement strategies are essential for enhancing farmer engagement and promoting environmentally friendly agricultural practices.

3.4.10.5 Technology Adoption and Barriers to Reducing Crop Burning

Despite the availability of various technologies, respondents reported a significant gap between awareness of these technologies and the desire for greater access and implementation support. The findings indicate that:

- Land clearing with heavy machinery (30%) is efficient but can damage the humus layer.
- Agricultural machinery for residue management is known about by 29% but expected by 71% of farmers.
- Residue collection systems (known about by 13%, expected by 62%) and residue valorisation schemes (known about by 20%, expected by 58%) are also in demand.

The biggest obstacles to adopting new technologies include high costs (80%), yield uncertainty (49%), and lack of support (16%). Addressing these requires financial aid, capacity building, and knowledge-sharing programmes (Goh et al., 2016; Obidzinski et al., 2012).

3.5 Conclusion and Recommendations

3.5.1 Conclusion

From the perspective of innovation and policy, while farmers acknowledge the importance of environmental sustainability, a small percentage still practice land burning. The 'zero burning' policy, implemented since 2014, has reduced this practice, but the higher costs and longer time required for alternative methods remain barriers, especially for small-scale farmers. The government has provided subsidies for replanting, but policy implementation faces challenges, particularly in terms of farmers' access to technology and financing. Financial support and skill development are crucial in promoting environmentally friendly farming practices.

Awareness of the negative environmental and health impacts of land burning has increased amongst farmers, although many remain unaware of the specific regulations prohibiting the practice. Existing policies require more intensive education and supervision to ensure effective implementation. Support from various stakeholders, including the government, private sector, and NGOs, is essential to help farmers understand and adopt environmentally friendly alternatives to land burning. Collaboration amongst stakeholders is key to enhancing the sustainability of the oil palm farming sector.

Last, the adoption of new technologies for land management and reducing plant burning is hindered by high costs and inadequate support. Farmers show a strong interest in environmentally friendly technologies, but limited access and implementation difficulties pose major challenges. Therefore, investment in technology, training, and stronger incentive policies is necessary to help farmers transition to more sustainable agricultural practices. Stakeholders must collaborate to address cost barriers and support farmers in implementing technologies that improve productivity and environmental sustainability.

3.5.2 Recommendations

Based on the analysis, the following recommendations are proposed for each section:

- Recommendation for Farmer Demographics and Education. The government and relevant institutions should provide more training and extension programmes to enhance farmers' skills, particularly in adopting modern agricultural technologies. Given the low interest of younger generations in farming, programmes that attract their participation – such as incentives or mentorship in agribusiness – should be introduced. Strengthening farmer groups or co-operatives can help improve farmers' bargaining power and

capacity in accessing markets, technology, and capital.

- Recommendation for Land Burning and 'Zero Burning' Policy. Greater government support is needed to provide environmentally friendly land management alternatives, such as mechanical technology or organic materials for land clearing. Subsidies or incentives should be offered to ease the burden on small-scale farmers who have limited access to technology and capital. Additionally, more intensive socialisation efforts regarding the 'zero burning' policy and clear sanctions for violations are necessary to ensure effective policy implementation.
- Recommendation for Environmental Awareness and Land-Burning Regulations. Educational and training programmes for farmers on land-burning regulations and their environmental and health impacts should be strengthened. Stricter monitoring of land-burning policy implementation and reinforcement of local-level regulations are essential to ensure compliance. Agricultural extension officers and related institutions should be more proactive in providing clear and easily understandable information to farmers about eco-friendly alternatives.
- Recommendation for Technology and Implementation of Alternative Crop Management. The government, private sector, and research institutions should collaborate further in developing and distributing technologies that reduce oil palm plant burning. Intensive training programmes for farmers on operating new technologies, along with financial support mechanisms, technical assistance, and improved access to appropriate machinery, are necessary to facilitate the adoption of sustainable alternatives to crop burning.

By following these recommendations, the oil palm farming sector is expected to become more environmentally sustainable, productive, and beneficial for farmers.

References

Abdul, A. (2023), *Merancang Kelapa Sawit Sebagai Komoditi Unggulan Nasional. Jakarta: PT. Literasi Nusantara Abadi Grup*. https://penerbitlitnus.co.id/portfolio/merancang-kelapa-sawit-sebagai-komoditi-unggulan-nasional/

Adrianto, A., A. Fauzi, and A.F. Falatehan (2019), 'The Typologies and the Sustainability in Oil Palm Plantation Controlled by Independent Smallholders in Central Kalimantan', In R. Kinseng, A. Dharmawan, D. Lubis, and A. Seminar (eds), *Proceeding Rural Socio-Economic Transformation: Agrarian, Ecology, Communication and Community Development*

Perspectives, London: Taylor & Francis. https://doi.org/10.1201/9780429280702-1

Aminah, S. (2015), 'Improving Land Dry Farmer Capacity Toward Adequate Food Security', *Jurnal Bina Praja*, 7(3), pp.197–210. https://doi.org/10.21787/jbp.07.2015.197-209

Antara News, (2015), 'Kebakaran Lahan Gambut', Jakarta: Antara News. https://www.antarafoto.com/id/view/537463/kebakaran-lahan-gambut

Astiti, P.D., A.F. Falatehan, and E.I.K. dan Putri, (2022), 'Implementasi Peremajaan Sawit Rakyat (Studi Kasus: KUD Tunas Muda Kabupaten Siak-Riau)', *Agribusiness Forum*, 12(2), pp.126–37. https://doi.org/10.29244/fagb.12.2.126-137

Babbie, E. (2020), *The Practice of Social Research* (15th ed.). Boston, MA: Cengage Learning. https://www.cengage.com/c/the-practice-of-social-research-15e-babbie/9780357360767/

Bessou, C., et al. (2017), 'Sustainable Palm Oil Production: A Review of Land-Use and Management Impacts'. *Journal of Cleaner Production*, 142, pp.379–398.

Carmenta, R. et al. (2021), 'Evaluating Bundles of Interventions to Prevent Peat Fires in Indonesia', *Global Environmental Change*, 67, 102246. https://doi.org/10.1016/j.gloenvcha.2020.102154

Creswell, J.W., and J.D. Creswell (2018), *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th ed.). Thousand Oaks, CA: SAGE Publications. https://us.sagepub.com/en-us/nam/research-design/book255675

Dwijanarko, B., F. Rianawati, D. Asysyifa, and J. Kehutanan (2020), Analisa Biaya Pembukaan Lahan Tanpa Bakar Di Desa Telaga Langsat Kecamatan Takisung Kabupaten Tanah Laut, (Cost Analysis Of Zero Burning Technique Of Clearing Land In Village Telaga Langsat District Takisung Districts Tanah Laut)', *Jurnal Sylva Scienteae*, 03:3.

Falatehan, A.F, and D.A.P. Sari (2020), 'Characteristics of Peat Biomass as an Alternative Energy and Its Impact on the Environment', *Solid State Technology,* 63(5). https://solidstatetechnology.us/index.php/JSST/article/view/5479

Falatehan, A.F., and B.I. Setiawan (2020), 'Economic Risk Characteristics of an Indonesian Palm Oil Value Chain and Identifying Sources of Uncertainty in Policy Making.', in V. Anbumozhi, F. Kimura, and S. Thangavelu (eds), *Supply Chain Resilience Reducing Vulnerability to Economic Shocks, Financial Crises, and Natural Disasters*. Singapore: Springer.

https://doi.org/10.1007/978-981-15-2870-5_5

Falatehan, A.F. and A.D. Siswanto (2014), 'Pengembangan Biodiesel Kelapa Sawit di Indonesia', *Jurnal Manajemen Pembangunan Daerah*, 6(1), Bogor: IPB University. https://doi.org/10.29244/jurnal_mpd.v6i1.24654

Falatehan, A.F., Y., Falatehan, and S.F. Hariyadi. (2023), 'Are Cooperatives Ready for the Digitalization of Smallholder Palm Oil Planations? Analysis of Farmer's Participation in Digitalization of A Village Cooperative Unit', *Journal of the International Society for Southeast Asian Agricultural Sciences (ISSAAS)* 29(1). https://scholar.ipb.ac.id/scopus/4615

Gaveau, D.L.A. et al., (2016), 'Rapid Conversions and Avoided Deforestation: Examining Four Decades of Industrial Plantation Expansion in Borneo', *Scientific Reports*, 6, pp.32017. https://doi.org/10.1038/srep32017

Goh, C.S., B. Wicke, A. Faaij, D.N. Bird, H. Schwaiger, and M. Junginger (2016), 'Linking Carbon Stock Change from Land-Use Change to Consumption of Agricultural Products: Alternative Perspectives', *Journal of Environmental Management*, 182, pp.542–56. https://doi.org/10.1016/j.jenvman.2016.08.004

Government of Indonesia. (2014), *Law No. 26/2014 on Ratification of the ASEAN Agreement on Transboundary Haze Pollution*. Jakarta: Government of Indonesia.

Hamza, M.A. and W.K. Anderson (2005), 'Soil Compaction in Cropping Systems', *Soil and Tillage Research*, 82(2), pp.121–45. https://doi.org/10.1016/j.still.2004.08.009

Hasyim, I. (2025), *Rencana Perluasan Perkebunan Sawit Prabowo Dinilai Berpotensi Meningkatkan Konflik Agraria*. Jakarta: Tempo.co https://www.tempo.co/lingkungan/rencana-perluasan-perkebunan-sawit-prabowo-dinilai-berpotensi-meningkatkan-konflik-agraria-1188419

Helmi, A. and M. Sasaoka (2018), 'Dealing with Socioeconomic and Climate-Related Uncertainty in Small-Scale Salt Producers in Rural Sampang, Indonesia', *Journal of Rural Studies*, 59(April), pp.88–97. https://doi.org/10.1016/j.jrurstud.2018.02.005

Jelsma, I. et al. (2017), 'Unpacking Indonesia's Independent Oil Palm Smallholders', *Land Use Policy,* 69, pp.281–97. https://doi.org/10.1016/j.landusepol.2017.08.012

Jong, H.N. (2024), '2023 Fires Increase Fivefold in Indonesia amid El Niño', *Mongabay*, 10 January. https://news.mongabay.com/2024/01/2023-fires-increase-fivefold-in-indonesia-amid-el-nino/

Ketterings, Q.M., T.T. Wibowo, M. van Noordwijk, and E. Penot (1999), 'Farmers' Perspectives on Slash-and-Burn as a Land-Clearing Method in Indonesia', *Forest Ecology and Management*, 120 (1–3), pp.157–69. https://doi.org/10.1016/S0378-1127(98)00532-5

Land Portal. (2020), 'Area Burned in Indonesia Fires "Greater than the Netherlands"'. *Land Portal*. 22 October. https://landportal.org/news/2020/10/area-burned-indonesia-fires-%E2%80%98greater-netherlands%E2%80%99

Obidzinski, K., R. Andriani, H. Komarudin, and A. Andrianto, (2012), 'Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia', *Ecology and Society*, 17(1), p.25. http://dx.doi.org/10.5751/ES-04775-170125

Plantation Key Technology Group (2023), Replanting Sawit: Pengertian, *Manfaat*, Syarat dan Peraturan Replanting. https://pkt-group.com/sawitnotif/replanting-sawit/

Purnomo, H. et al. (2017), 'Fire Economy and Actor Dynamics in Indonesia', *Forest Policy and Economics,* 78, pp.21–31. https://doi.org/10.1016/j.forpol.2017.01.001

Rosyadi (2023), 'Implementasi Model Green Economic pada Kegiatan Replanting Kebun Kelapa Sawit (Studi Kasus Kabupaten Ketapang Kalimantan Barat)'. *Jurnal Ilmiah Ekonomi Bisnis*, 28(2), August. https://doi.org/10.35760/eb.2023.v28i2.7325

Roundtable on Sustainable Palm Oil (RSPO) (2018), *The RSPO Principles and Criteria (RSPO P&C) for the Production of Sustainable Palm Oil 2018*. Kuala Lumpur: RSPO. https://rspo.org/wp-content/uploads/rspo-principles-and-criteria-2018-approved-15-november-2018-english.pdf

Safitri et al. (2024), 'Analysis of the Impact of the Plantation Sector on Economic Growth Referring to the 2021 Indonesian SDGs', *Studi Ekonomi dan Kebijakan Publik (SEKP),* 2(2), pp.89–99. https://doi.org/10.35912/sekp.v2i2.2480

Santika, T. et al. (2019), 'Does Oil Palm Agriculture Help Alleviate Poverty? A Multidimensional Counterfactual Assessment of Oil Palm Development in Indonesia', *World Development*, 120, pp.105–17. https://doi.org/10.1016/j.worlddev.2019.04.012

Sari, D.A.P., A.F. Falatehan, and R.Y. Ramadhonah (2018), 'The Social and Economic Impacts of Peat Land Palm Oil Plantation in Indonesia', *Journal of Physics: Conference Series,* 1364. https://iopscience.iop.org/article/10.1088/1742-6596/1364/1/012017

Sofiyuddin, M. et al. (2021), 'Sustainable Land Preparation for Farmer-Managed Lowland Agriculture in Indonesia', *Forest Policy and Economics*, 130, pp.102534. https://doi.org/10.1016/j.forpol.2021.102534

Statista (2025), *Palm Oil Industry in Indonesia – Statistics & Facts*. Palm oil industry in Indonesia- statistics & facts | Statista [Accessed 22 July 2024]

Tacconi, L. (2016), 'Preventing Fires and Haze in Southeast Asia', *Nature Climate Change*, 6(7), pp.640–43. https://doi.org/10.1038/nclimate3008

United States Department of Agriculture (USDA) (2025), *Indonesia Palm Oil Area, Yield and Production.* https://ipad.fas.usda.gov/countrysummary/default.aspx?id=ID&crop=Palm%20Oil. [Accessed 22 July 2025].

Veronice, Helmi, Henmaidi, and A. Arif (2018), 'Capacity And Institutions Building of Small Farmers in the Cluster Area of Agriculture Through Knowledge Management Approach', *Journal of Applied Agricultural Science and Technology*, 2(2), pp.1–10.

World Bank. (2011), *Oil Palm Smallholder Schemes in Indonesia*. Washington, DC: World Bank.

Chapter 4
Case Study on Reducing Crop Burning in ASEAN Member States: Cassava Production in Lao PDR

Sayvisene Boulom

4.1 Introduction and Background to the Study

Crop burning has emerged as a significant environmental, economic, and public concern across the Association of Southeast Asian Nations (ASEAN) countries, and the trend of agricultural residue burning has been increasing in Asia (Vadrevu et al., 2019). This is associated with agricultural burning, using fire for vegetation management in open areas such as farmland, orchards, rangelands, and forests. Agricultural burning is a type of open burning where the entire crop is deliberately set on fire, such as slash-and-burn farming in forest areas, and using fires for land clearing of large fields. Agricultural burning has contributed significantly to environmental pollution, while high recycle costs and lack of labour has created further challenges (Lin and Begho, 2022).

To deliver the comprehensive framework and roadmap for ASEAN Member States (AMSs), the Guidelines for Sustainable Agriculture (ASEAN, 2023) and the Guidelines on the Reduction of Crop Burning (ASEAN, 2024) are being developed to enhance sustainable agriculture practice, reduce crop-burning practices, improve soil and human health, and protect the environment. In line with this activity, case studies for crop-burning reduction in AMSs are required to support the implementation of the guidelines. The study in the Lao People's Democratic Republic (Lao PDR), investigated cassava burning practices, sustainable production methods and relevant policies.

4.2 Study Methodology

The study locations were in Vientiane Capital and Xayabouly Province, which are major cassava production areas and close to export markets, such as Thailand. The sites comprise cassava starch factories, collecting points, many cassava producers.

A purposive sampling method was used to select the sample. The research team sent an official letter to provincial and district agriculture and fishery offices and the officers worked with village heads to make appointments with farmers and other respondents such as local cassava collectors and traders. The farmers

voluntarily participated in the interviews. The data were mainly used for descriptive analysis.

4.3 Study Results

4.3.1 Respondent Identity

4.3.1.1 Respondent Information

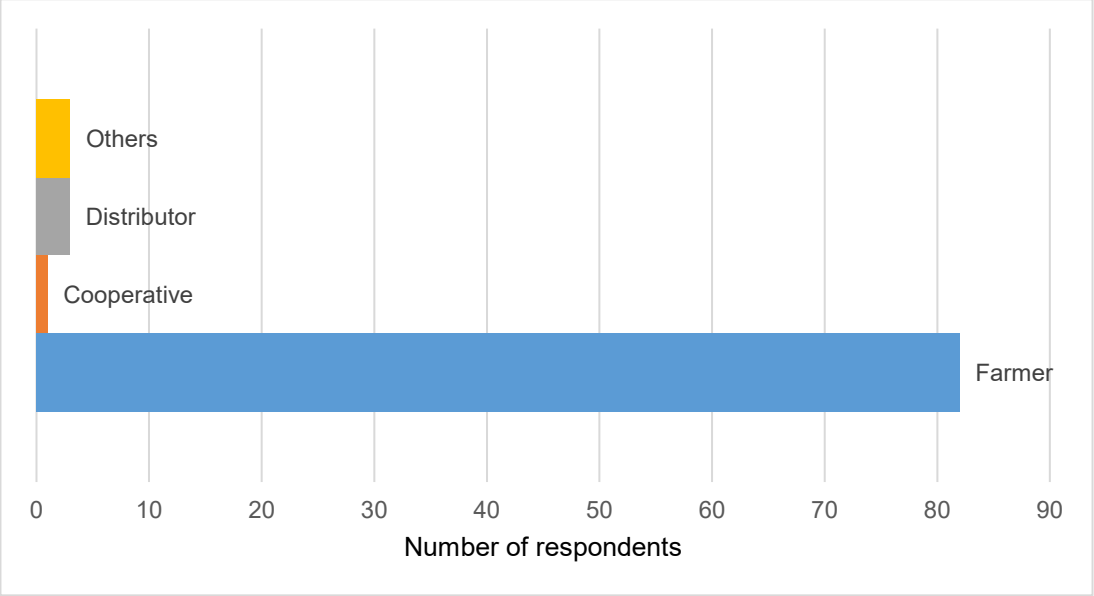
The results of the preliminary survey were obtained from 89 farmers in three districts in the cassava production area of Lao PDR: 79 farmers were from Sengthong district, Vientiane Capital, five participants were from Long district, and five were from Paklay district, Xayabouly Povince. The interview respondents were evenly balanced by gender with 45 male farmers (49%) and 44 female farmers (51%).(Table 4.1). The majority of participants in the survey are farmers (82). There is also one co-operative, three distributors or traders, and three others (Figure 4.1). The result revealed that the education level of the respondents was mainly at primary school level (32%) and secondary school level (47%), while 3.2% of farmers were illiterate (Figure 4.2).

Table 4.1. Distribution of Respondents by Districts and Gender

Respondent distribution		Gender of respondents	
District	Number of respondents	Gender of respondents	Number of respondents (%)
Sengthong	79	Male	55
Long	5	Female	45
Paklay	5		

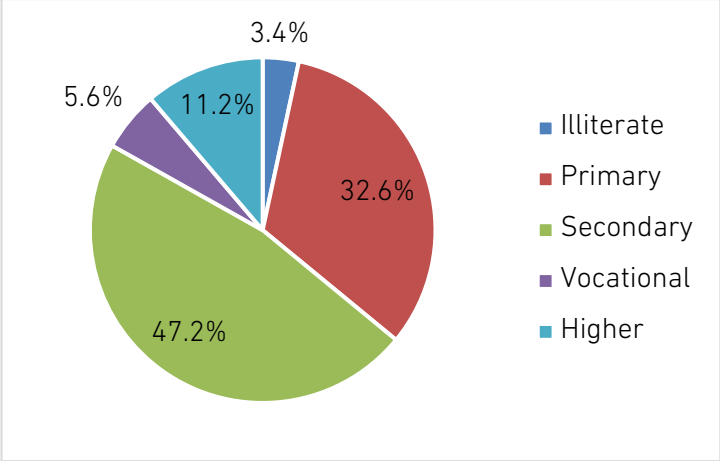
Source: Author's analysis.

Figure 4.1. Occupation of Respondents



Source: Author's analysis.

Figure 4.2. Education Level of Respondents



Source: Author's analysis.

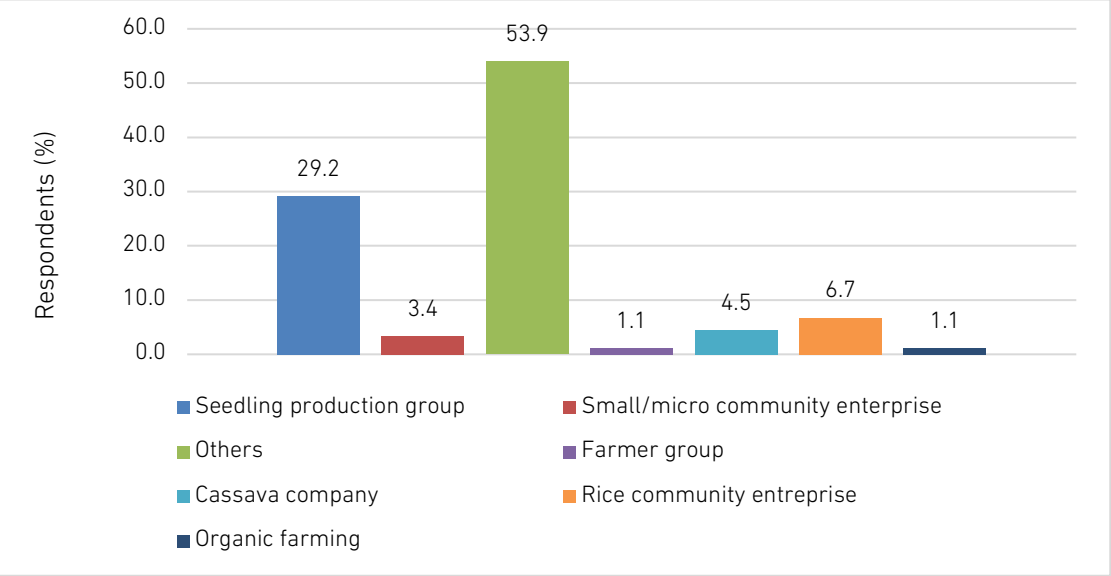
4.3.1.2 Respondents' Membership of Farmers' Associations

In Lao PDR, farmer organisations and co-operatives have been promoted by the Department of Agriculture Extension and Cooperative, Ministry of Agriculture and Forestry since 2010. This effort was strengthened by the issuance of the new Decree on Farmer Groups and Cooperatives (No606/GOL on 26 November 2020). The Decree aims to promote and develop products and services, create new businesses, support agricultural growth, foster a sustainable economy for poverty

reduction, and improve the rural livelihood of people in Lao PDR.

The results of the study show that the respondents had mainly joined seed production groups. Farmers were also members of rice community enterprises and cassava companies, where they could sell the agricultural products. Some farmers were also members of small or micro-community enterprises that provided micro finance services (Figure 4.3).

Figure 4.3 Respondents' Membership Status in Farming Associations



Source: Author's analysis.

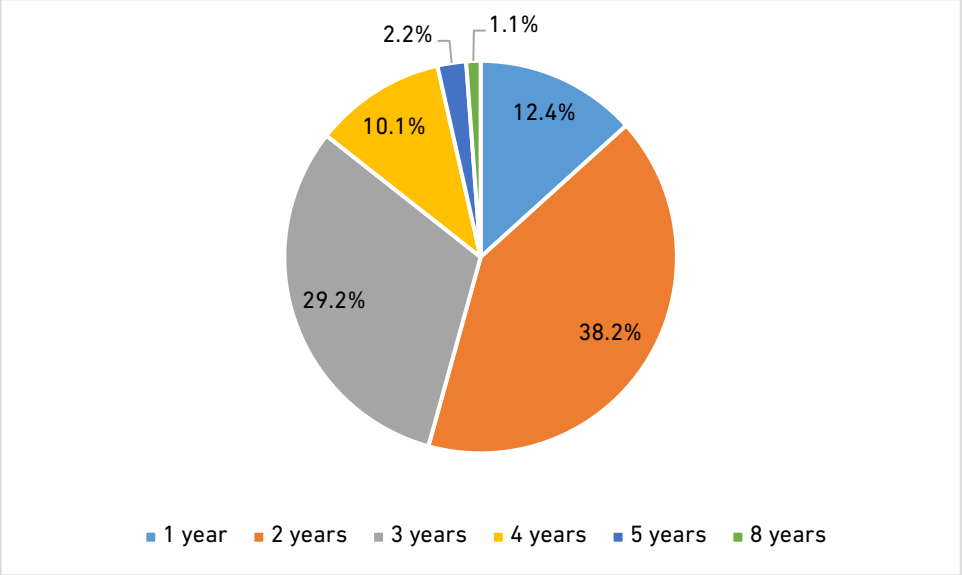
4.3.2 Current Status of Cassava Production in Lao PDR

4.3.2.1 Cassava Varieties Used in the Study Areas

Cassava production has become one of the most important cash crops in Lao PDR in recent years and can generate not only revenue for the country but also an essential income for farmers. Many collecting and starch factories have also been set up in different parts of the country.

Figure 4.4 shows that cassava production in the study areas only started in recent years, with 29% of farmers starting 3 years ago, and 38% starting 2 years ago.

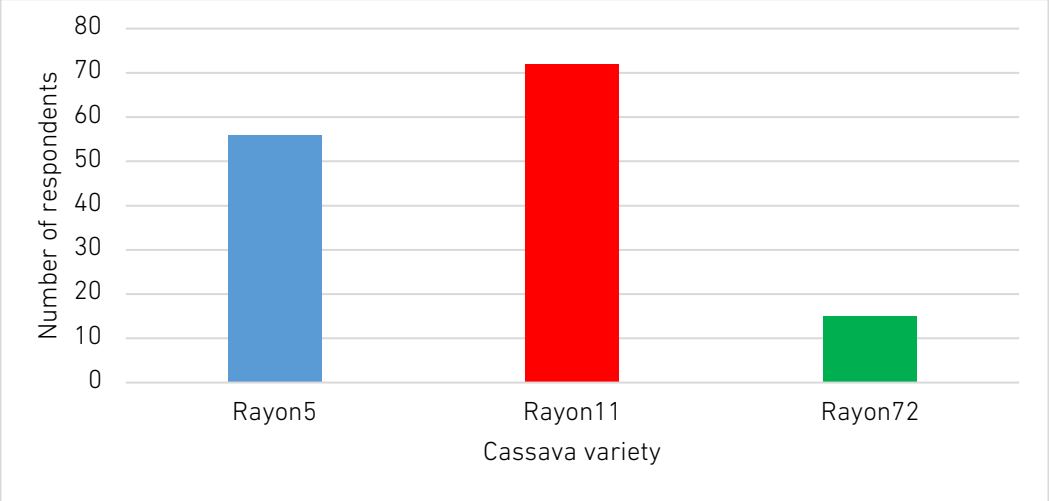
Figure 4.4. Respondents' Years of Experience in Cassava Cultivation



Source: Author's analysis.

Selecting the right cassava varieties are key for to ensure a better yield, resistance to diseases such as cassava mosaic disease, and adaptation to different environmental conditions. The cassava variety selection can also vary according to the intended use (starch or animal feed) or according to the availability of planting materials. In the study areas, farmers used mainly cassava varieties from Thailand (Figure 4.5). Three varieties — Rayon 5, 11, and 12 — are known for both starch production and dry chips. Rayon 11 was the most selected variety by respondents of the study. They reported that Rayon 11 was widely available in the villages; farmers get it from their neighbours, companies, and starch factories, which provide it due to its high starch content and its suitability for these areas.

Figure 4.5. Cassava Varieties Cultivated by Respondents



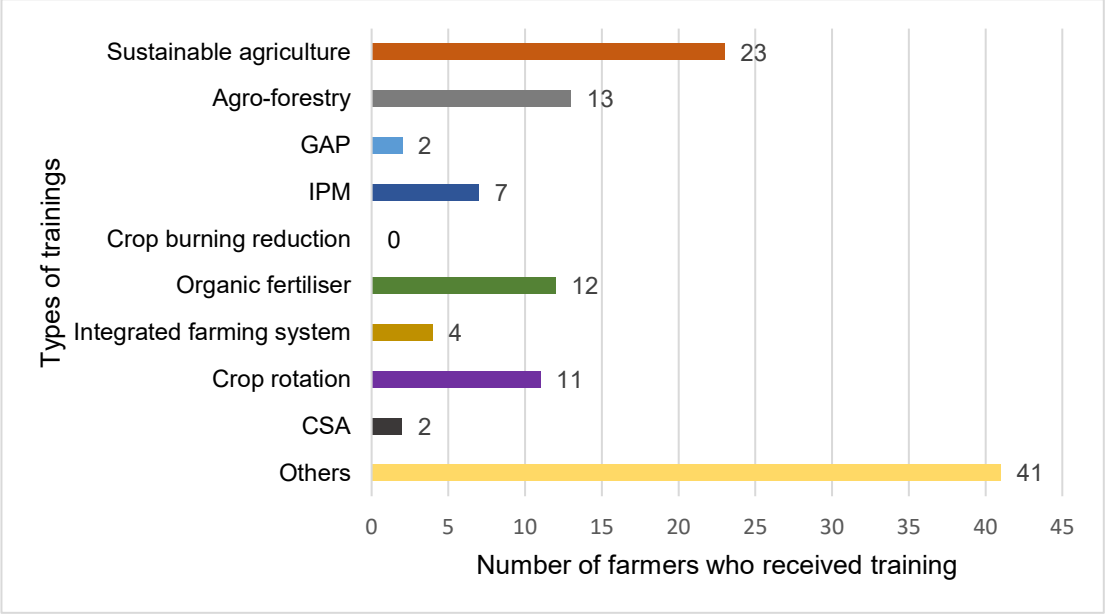
Source: Author's analysis.

4.3.2.2 Extension Services and Support Received from the Agent

Reducing crop burning requires a variety of approaches and extension services and supporting agents will play an important part in future success. The results of our studies reveal that training and extension services have been introduced in the study areas through a range of agencies such as the Department of Agricultural Extension and Cooperative, the Department of Agriculture and the National Agriculture and Forestry Research Institute, as well as starch companies and other development partners. Figure 4.5 reveals that cassava production is an important commodity for Lao PDR. However, the cultivation practices are largely based on monocropping so farmers have received training on sustainable agriculture, agroforestry, applying organic fertiliser, crop rotation, integrated pest management, and good agriculture practices.

Cassava plantation areas often practise slash-and-burn methods and extension workers in the regions have recently introduced new initiatives. Technical support from provincial and extension workers provides a range of training topics for cassava producers. The result of the survey showed that farmers undertook training courses on sustainable agriculture (23 times), agroforestry (13 times), organic fertiliser application (12 times) and crop rotation (11 times) (Figure 4.6.). These training courses aimed to help farmers in sustainable cassava production systems.

Figure 4.6. Types of Training and Extension Services Received by Respondents



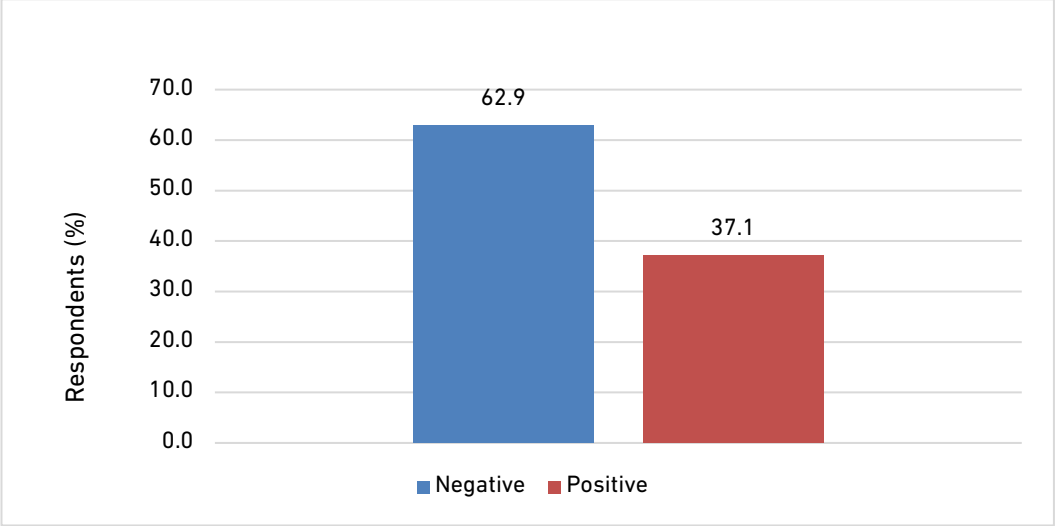
Source: Author's analysis.

4.3.3 Respondents' Opinions from the Study

4.3.3.1 Respondents' Views of the Effects of Burning Cassava on the Environment

Research shows that agriculture burning, including field preparation, opening new field plantations, and burning agricultural waste has a negative effect on the environment (Mathur and Srivastava, 2019). Farmers in South and Southeast Asia generally practise agricultural burning, which leads reduces soil fertility (Lin and Begho, 2022). Our study showed that the majority of farmers and other respondents agreed that crop burning had negative effects on the environment. They said that during field preparation in March, April, and May farmers started clearing their land and burning agricultural residues. However, one-third of farmers had a different opinion. They claimed that burning residues can bring quick fertiliser to their soil and destroy pests and diseases for their new crops, like young cassava (Figure 4.7).

Figure 4.7. Respondents' Opinions on Crop Burning



Source: Author's analysis.

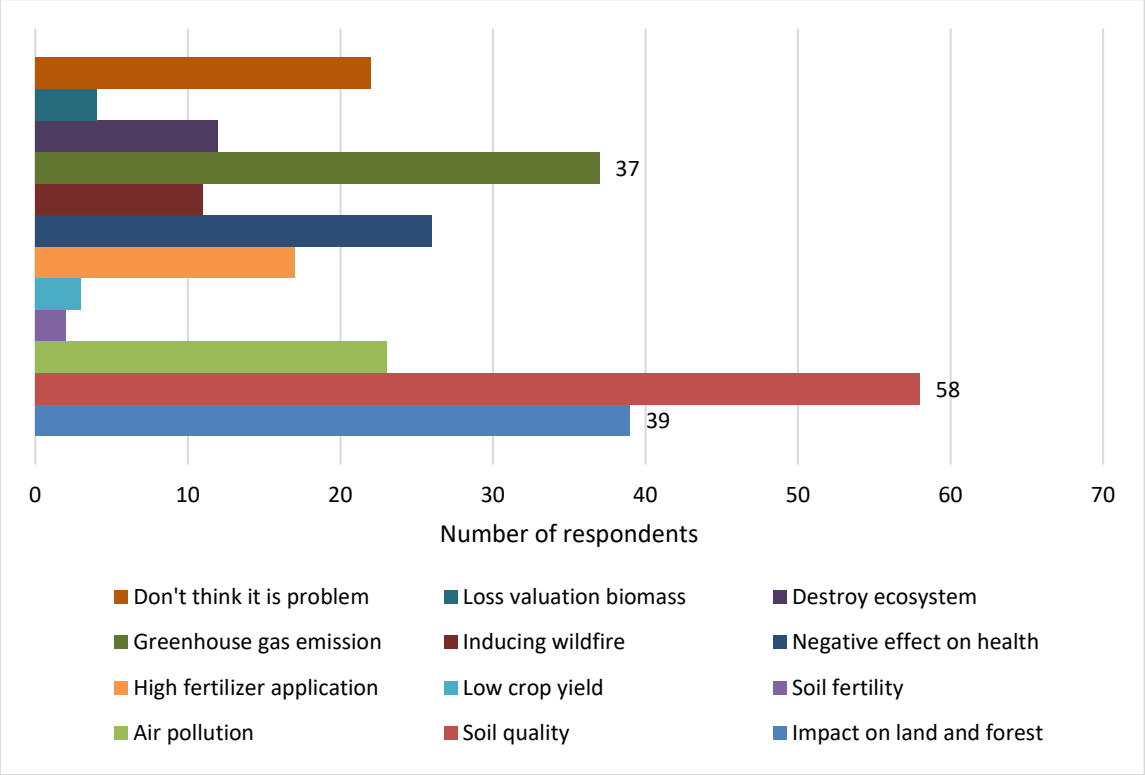
4.3.3.2 Respondents' Views of Problems Caused by Crop Burning

In recent years, challenges associated with crop burning have become an important issue in relation to sustainable agriculture production, health concerns, and environmental effects. Both farmers and the public acknowledge these issues.

Our study results show that farmers and respondents were aware of the impacts of practising crop burning. They report that the most significant problems of were reduced soil quality, negative effects on land and forests, increasing greenhouse gas emissions, and negative effects on human health and air pollution. In addition, farmers realised that burning crop residues had direct agronomic effects such as destroying ecosystems and biomass, which is linked to low soil fertility (Figure 4.8).

Currently, farmers need to apply high levels of fertiliser to maintain agricultural productivity and decent income.

Figure 4.8. Respondents' Views on the Impact of Induced Crop Burning



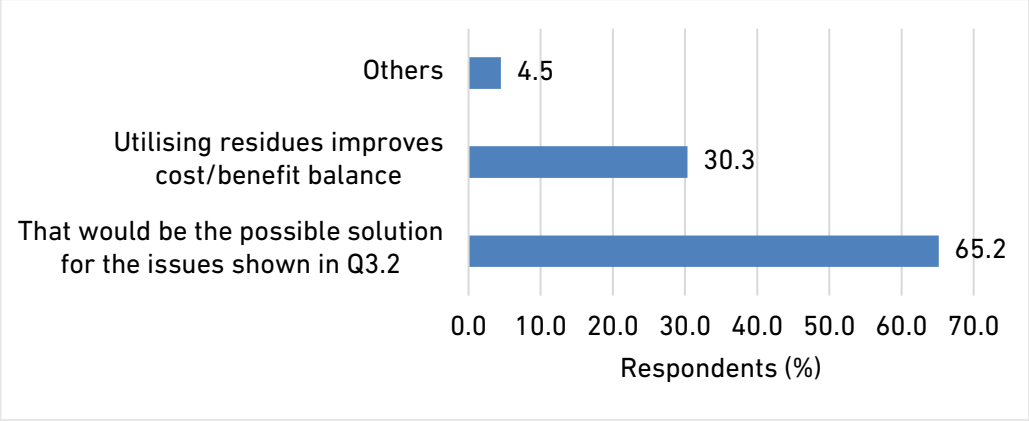
Source: Author's analysis.

4.3.3.3 Respondents' Expectations about Reducing Crop Burning?

Respondents' perceptions about expectations around reductions in crop burning reflect the challenges they acknowledge in their farming practices. We asked further, specific questions about these expectations in Lao PDR. Their main concerns were to reduce the negative effects from burning crop residue, cited by 65% of respondents (Figure 4.9).

However, 30% of respondents expected that crop residue utilisation could enhance cost-benefit balance on the farms. For example, cassava leaves could be fermented for cattle feeds and mixed with rice bran and beans for poultry and pig feeds.

Figure 4.9. Respondents' Expectation around Reduced Crop Burning



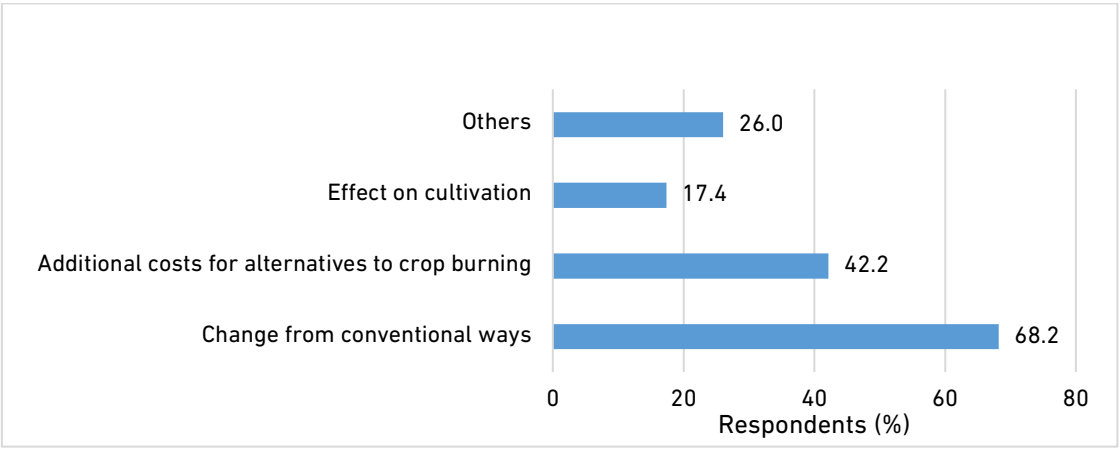
Note: Q3.2 What is the problem induced by crop burning?
Source: Author's analysis.

4.3.3.4 Respondents' Concerns about Reducing Crop Burning?

In Lao PDR, the majority of farmers still practise subsistence production systems and burning agriculture waste and brush is a common practice because it is the cheapest method. In this study, respondents also confirmed that the practices persist amongst farmers.

The results revealed that 68% of farmers were concerned about changing from conventional ways of production, while other farmers expected that the alternative ways would add extra production costs. Finally, farmers were also not sure about the new methods, which can affect the productivity of their cultivation (Figure 4.10).

Figure 4.10. Respondents' Concerns about Reduced Crop Burning



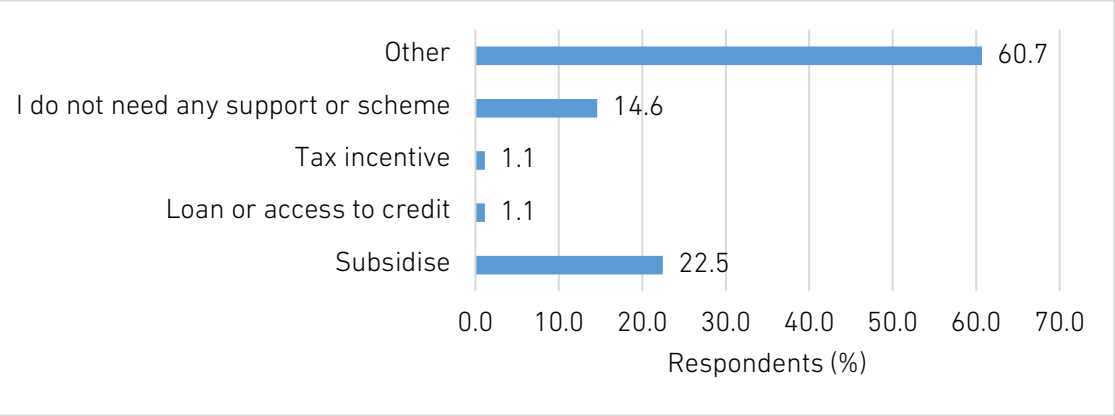
Source: Author's analysis.

4.3.3.5. Financial Support Available to Respondents to Promote A Reduction in Crop Burning?

In the study areas, there was financial support to promote crop-burning reduction. About 22% of farmers received subsidised funds from the local government to not burn. However, the majority of farmers did not know about the scheme, or they were concerned about other challenges. The respondents were not familiar with financial support to help them to stop burning and to reduce pressure on the environment (Figure 4.11).

Evidence from China shows that local governments there prioritise subsidised initiatives for practices and machinery to reduce crop burning (Chen et al., 2019).

Figure 4.11. Respondents' Awareness of Financial Support to Reduce Crop Burning



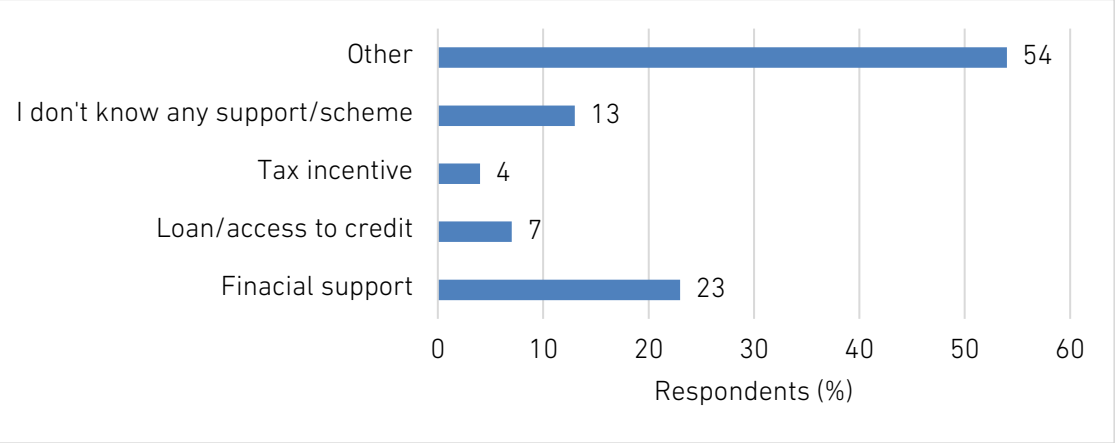
Source: Author's analysis.

4.3.3.6 Financial Support Needed by Respondents to Reduce Crop Burning?

A specific question was asked about the type of financial support that farmers need to promote a reduction in crop burning. The result confirmed that the majority of farmers were concerned with other aspects of cassava production, like cassava prices, while a small number of respondents stated that they needed financial support to reduce crop burning. The main reason for this is that they were not aware of any support or financial scheme. Furthermore, some farmers had expected new initiatives to promote sustainable agricultural production, including crop-burning reduction. For example, 7% of farmers stated a need for access to credit and 4% requested access to tax incentives (Figure 4.12).

Examples from India show that financial solutions could help farmers to adopt agriculture residue management practices (Singh et al., 2022).

Figure 4.12. Types of Financial Support Needed to Reduce Crop Burning



Source: Author's analysis.

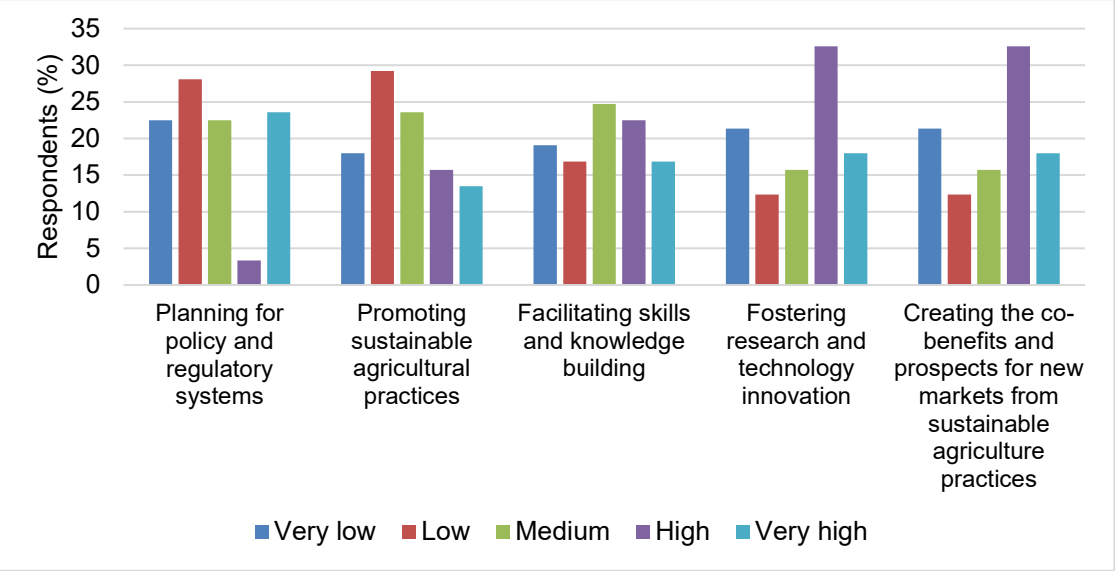
4.3.4 Activities to Reduce Crop Burning

4.3.4.1 What Activities Should Be Prioritised to Reduce Crop Burning?

Reducing agricultural burning in Lao PDR does not need only capacity building activities, but also supportive policies. The result (Figure 4.13) of the survey showed priority activities and policies that could be adopted to promote agriculture residue or waste burning reduction. These were the dual benefits of creating new markets from sustainable agricultural practices and fostering research and technology innovation. Farmers said that if there was a market for reused or recycled waste, they would want to join the scheme However, farmers were not confident about such projects without the scientific research results to back them up and cost-effective implementation plans.

Other priorities are the promotion of sustainable agricultural practices like integrated pest management, good agricultural practices, climate-smart agriculture, and crop rotation. Planning for policy and regulation systems such as the promotion of innovative technology and financial support is also important.

Figure 4.13. Respondents' Opinions on the Activities that Should Be Prioritised



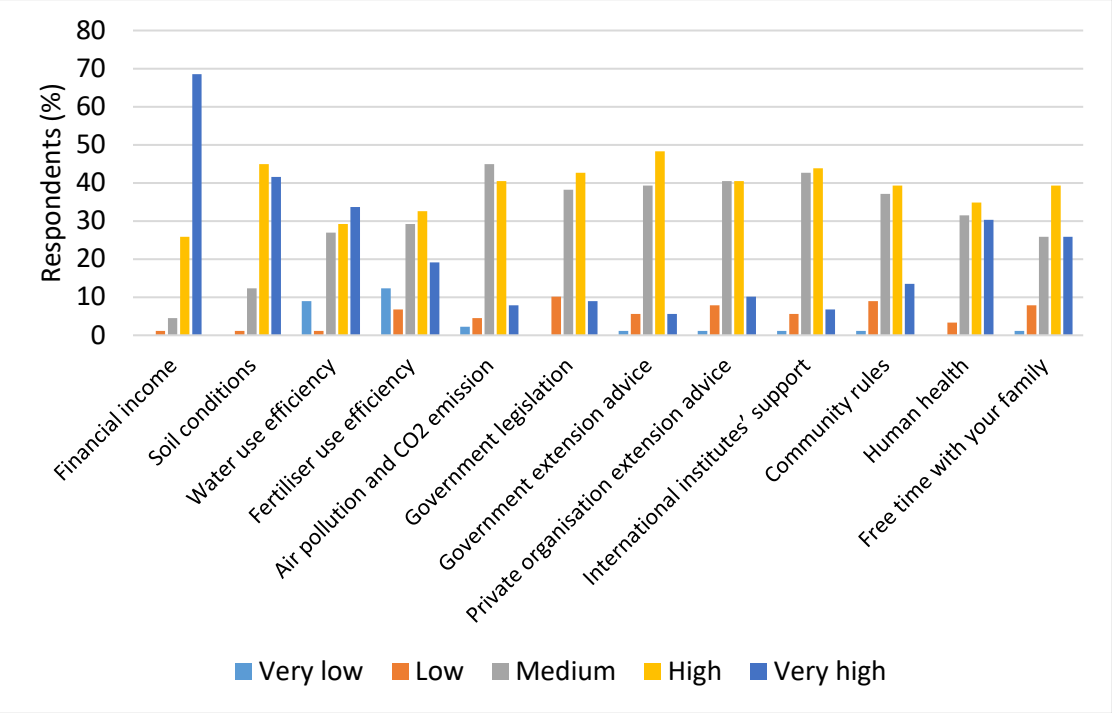
Source: Author's analysis.

4.3.4.2 Factors Influencing Respondents' Agricultural Decision-Making?

Sustainable agricultural practices, including climate-smart agriculture and good agricultural practices have been an important training topic under the Department of Agriculture and the Department of Agriculture Extension and Cooperative to reduce agriculture burning, climate change and create a better environment. The study also explored the decision-making of farmers in selecting these practices. The most important three factors were income generation; soil condition improvement, and water-use efficiency (Figure 4.14).

Farmers also expressed a need to have clear government policies and get better agriculture extension services, while environmental air pollution and negative health effects were also important considerations.

Figure 4.14. Rating Key Factors in Agricultural Decision-Making



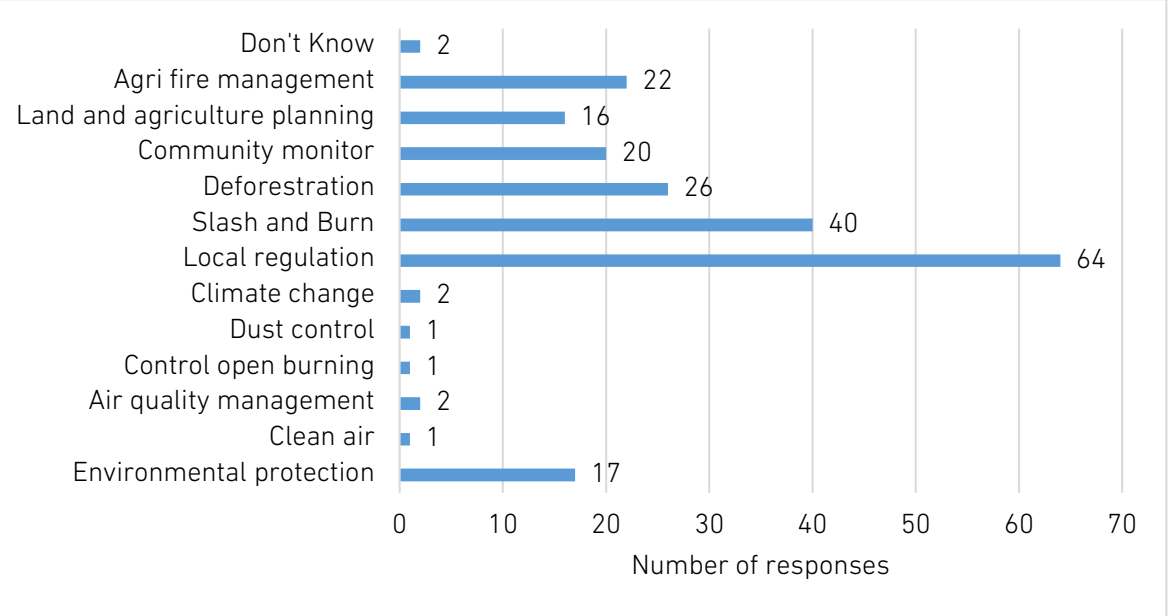
CO2 = carbon dioxide.
Source: Author's analysis.

4.3.5 Crop-Burning Reduction Policies

4.3.5.1 Respondents Awareness of Policies to Reduce Crop Burning

Reducing crop burning is a complex challenge which are needs a multisectoral approach and different polices tailored to local contexts. The study shows (Figure 4.15) that respondents knew about the various polices in Lao PDR that aimed to limit crop residue burning in the field. Key policies mentioned were local regulations that prohibited slash-and-burn and deforestation and were announced in the villages. During the field preparation before the new cropping season, agricultural fire management and community monitoring were often practised in the study areas. Land and agriculture planning and environmental protection were also mentioned by the respondents.

Figure 4.15. Respondents Knowledge of Policies to Reduce Crop Burning



Source: Author's analysis.

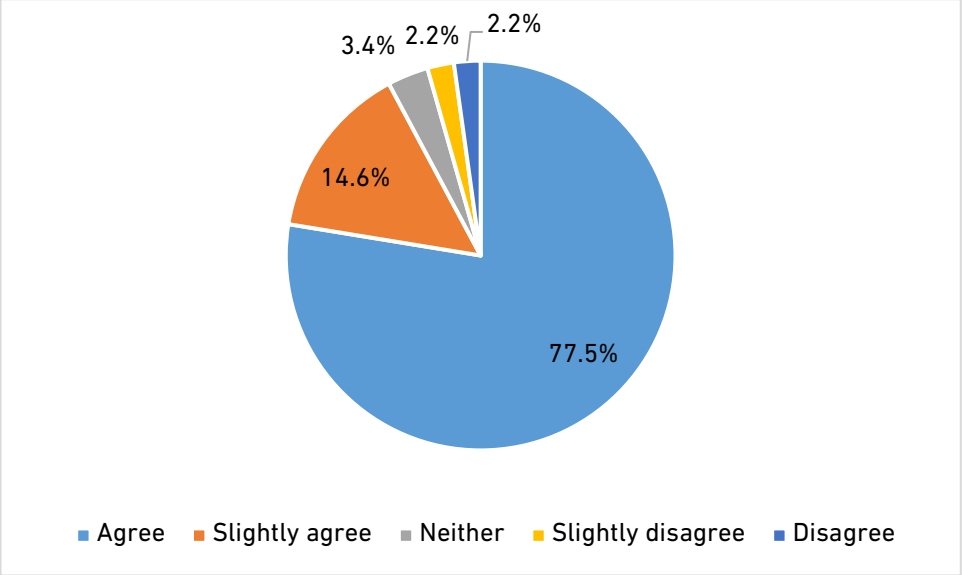
4.3.5.2 Respondents Views on the Promotion of Crop-Burning Reduction Policies

Various policies have been promoted in Lao PDR to reduce crop burning and its practices. Farmers acknowledged this (Figure 4.15), mentioning local regulations on crop burning, bans on slash-and-burn and deforestation, and environmental protection. The majority (77.5%) of respondents agreed with these policies (Figure 4.16).

However, the survey showed that a small number of farmers and respondents (4%) disagreed that crop burning caused the main problem for human health and had a negative impact on environment. They claimed that heavy industry, mining, and pollution from cars in big cities also create these problems.

Farmers also suggested that they need more assistance for policy enforcement on the ground and pilot models for small farm size should set in rural areas where farmers can visit and exchange knowledge and practices.

Figure 4.16. Do You Agree with Policies to Reduce Crop Burning?



Source: Author's analysis.

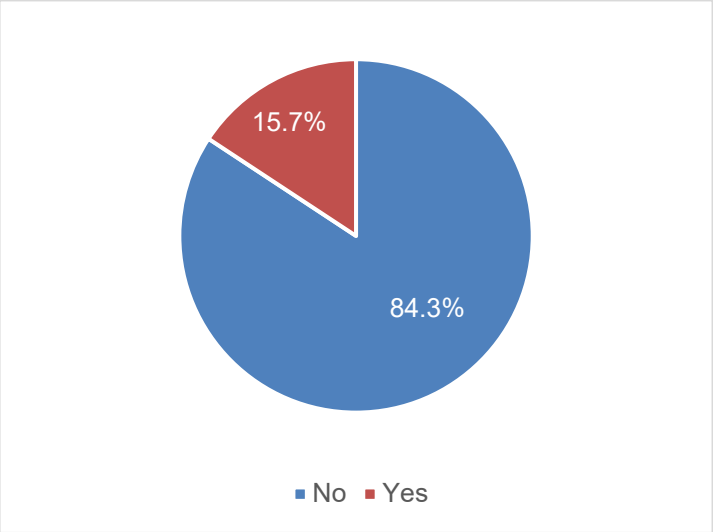
4.3.5.3 Respondents' Knowledge of Non-Formal Rules, Customary Rules, or the Application of Local Wisdom to Reduce Crop Burning

Policies on reducing crop burning have been indirectly included in different regulations in Lao PDR, such as a ban on agricultural burning and deforestation, but enforcement remains challenging.

The survey revealed that non-formal regulations and practices exist in the study areas, for example, 13% of the respondents said that the local authority had monitored and controlled field burning in conservation forest areas and community forests, and farmers also used pesticides to control weeds.

Another concern was that farmers did not recognise conservation zones and cultivation areas. The survey showed that 84% of farmers did not recognise non-formal regulations (Figure 4.17).

Figure 4.17. Are Respondents Aware of the Non-Formal Applicable Rules Concerning Reduced Crop Burning?



Source: Author's analysis.

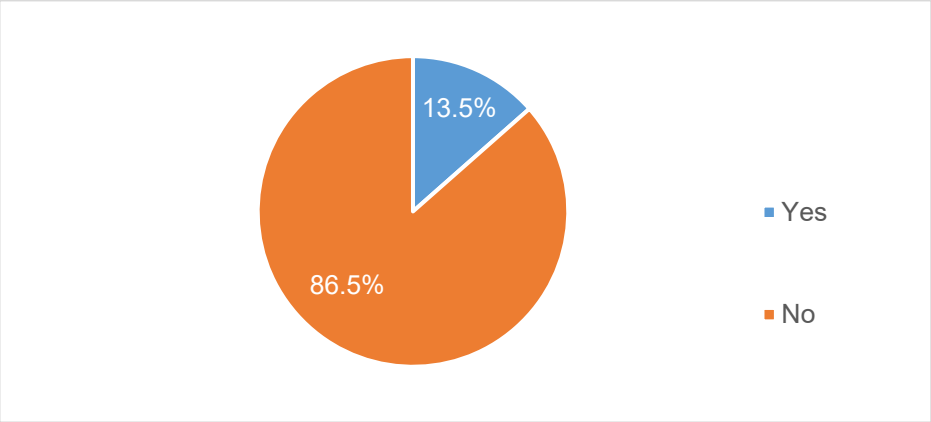
4.3.6 Capacity Building and Knowledge-Sharing

4.3.6.1 Respondents' Knowledge of Opportunities for Capacity Building and Knowledge-Sharing to Promote a Reduction in Crop Burning

Reductions in crop burning needs to be enhanced by capacity building and knowledge-sharing to promote sustainable agriculture practices and create a better environment. The survey results showed that a small number of farmers gained knowledge through a variety of training courses as part of government pilot projects such as the Department of Agriculture Extension Services and non-profit organisations like the Agroecology Learning Alliance in South East Asia network, Stichting Nederlandse Vrijwilligers (SNV), and the Food and Agriculture Organization. For example, 13.5% of respondents had benefited from capacity building and knowledge-sharing (Figure 4.18).

Knowledge-sharing in the study area has generally been limited to demonstrations and project-based activities. So, when the projects end, local extension workers are limited in their capacity to continue the training and implementation.

Figure 4.18. Have Respondents Benefited from Opportunities for Capacity Building and Knowledge-Sharing to Reduce Crop Burning?



Source: Author's analysis.

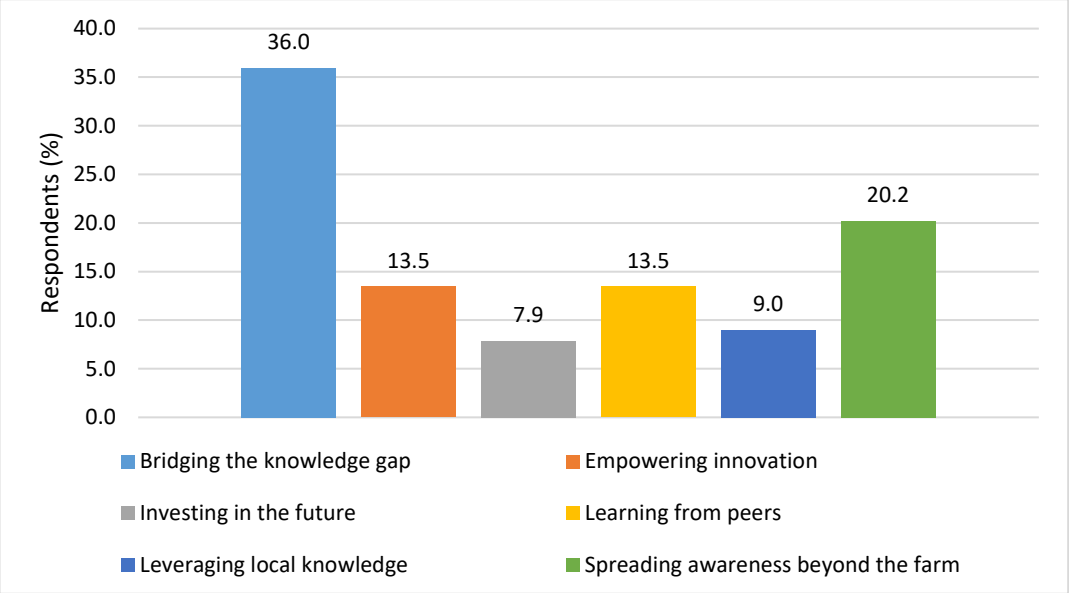
4.3.6.2 Opportunities Needed to Enable Respondents to Reduce Crop Burning?

It is interesting to note that capacity building needs were identified in the survey to manage crop burning in Lao PDR. Figures 4.19 and 4.20 show that different priorities were raised by farmers and respondents. The top two capacity building activities were bridging the knowledge gap and spreading awareness of crop-burning reduction with other farmers and farmer groups.

Greater attention should be paid to barriers farmers face when reducing agricultural burning. Innovative technologies and the development of markets for crop residue were given as important factors to enable farmers to reduce crop burning. Additionally, there needs to be greater awareness about the need for a reduction in crop burning for all stakeholders, from farmers to consumers. Consumers and development partners can push for the creation of a clean and green market. We have to create collaboration between government, private development partners and farmers such as the Public–Private Community Partnership to promote reductions in agricultural waste burning and better soil, environment, and human health.

Leveraging local knowledge and investing in the future were important for farmers, because they allow for the fast adoption of technology and practices like composting cassava leaves for animal feed. For example, sustainable economic models including carbon credits and biochar could be a future investment and best practice for farmers.

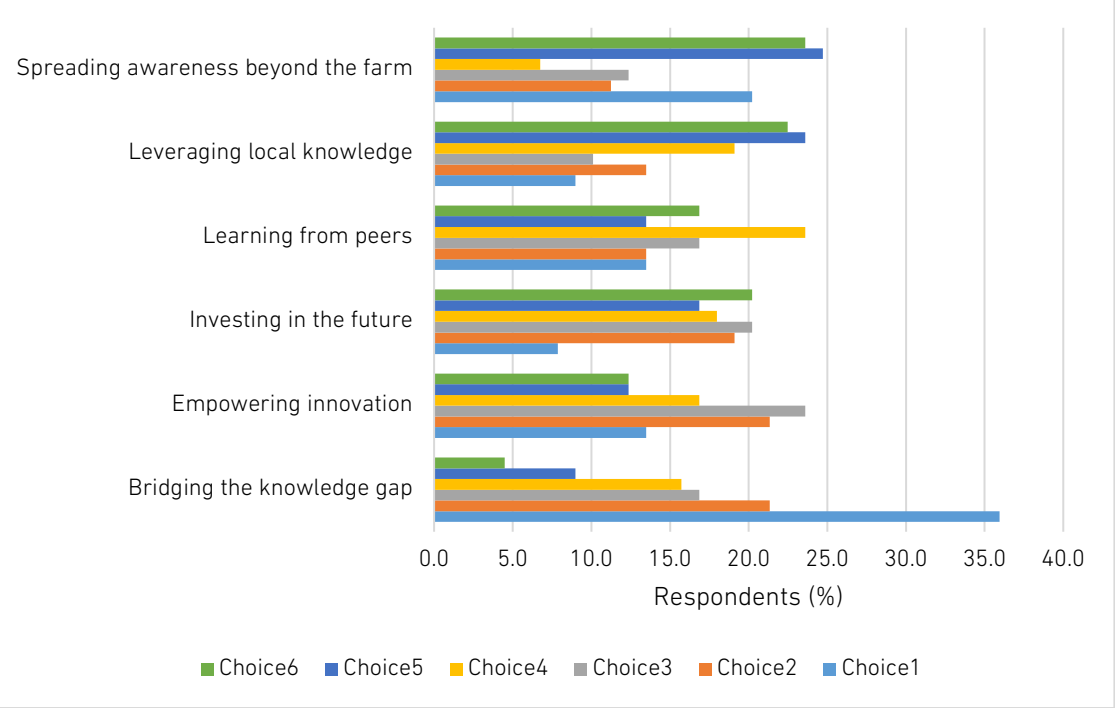
Figure 4.19. Respondents' Ranking of Capacity Building Needs



Source: Author's analysis.

There is a need for capacity building to empower innovation and peer learning. Cassava production in Lao PDR mainly uses a monocropping system, contributing to soil degradation and erosion in mountainous areas. New integrated farming systems and crop rotation could help to mitigate this through, for example, turning cassava waste – stems and root waste – into biochar, which can be returned to the field to maintain soil fertility. To support this, a model should be developed that can show farmers, through farmer-to-farmer learning schemes, how to implement practices to reduce casava burning.

Figure 4.20. Respondents' Priorities for Capacity Building to Reduce Crop Burning



Note: Levels of priority are numbered 1–6, with 1 being the greatest need and 6 being the least important need.
Source: Author's analysis.

The results from Figure 4.20 show capacity building needs in order of importance, graded 1–6., where 1 is the most important need. The main priority that farmers identified was bridging the knowledge gap and they had a wish to introduce more new, innovative technologies and practices rather than their more traditional, familiar ones. The second and third priority areas were similar – empowering innovation and investing in the future. The fourth area of importance to famers was learning from peers, acknowledging that peer learning is important for cassava production and adaptation. Priorities 5 and 6 were leveraging local knowledge and spreading awareness beyond the farm.

4.3.7 Involving Stakeholders

4.3.7.1 Respondents Knowledge and Expectations of Co-operative Activities to Reduce Crop Burning

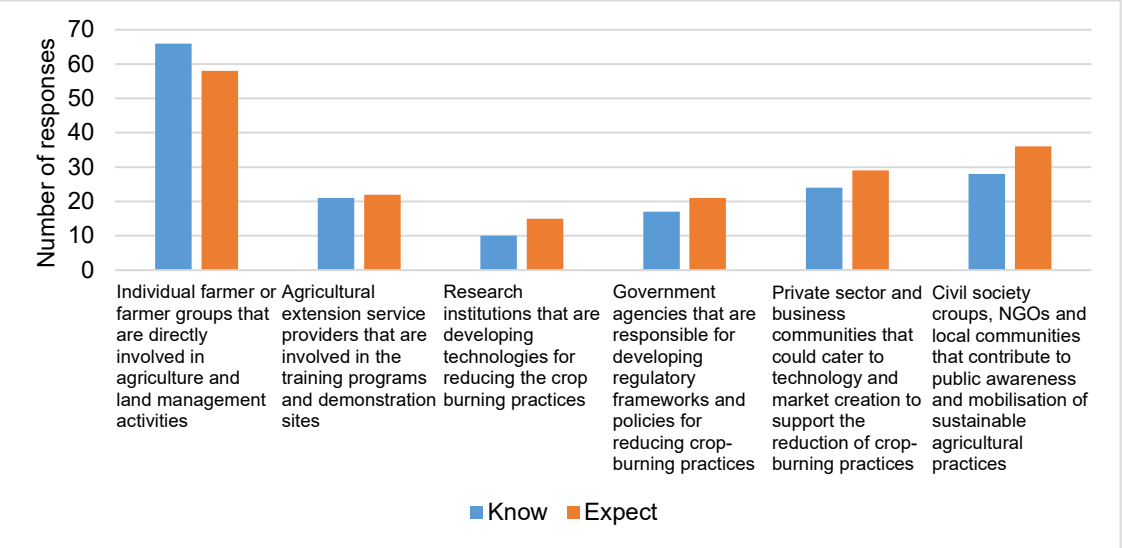
It is generally acknowledged that burning agricultural waste or crops produces particulate matter 2.5 micrometres or smaller that affects urban areas. The survey investigated co-operative activities that could promote a reduction in crop burning

in Lao PDR. Figure 4.21 shows stakeholders' knowledge and expectation of possible collaborative activities that could reduce crop burning.

Results indicate that two highest-ranked forms of co-operation were between individual farmers and farmer groups that were directly involved in agriculture and land management activities. In addition, civil society organisations, non-governmental organisations, and local communities also contribute to public awareness and mobilisation of sustainable agriculture practices.

The second level of co-operative activities were undertaken by private sector and business communities that create technology and markets to reduce crop-burning practices and agriculture extension service providers that are involved in training programmes and demonstrations.

Figure 4.21. Co-operation Activities that Respondents Know and Expect



NGO = non-governmental organisation.
Source: Author's analysis.

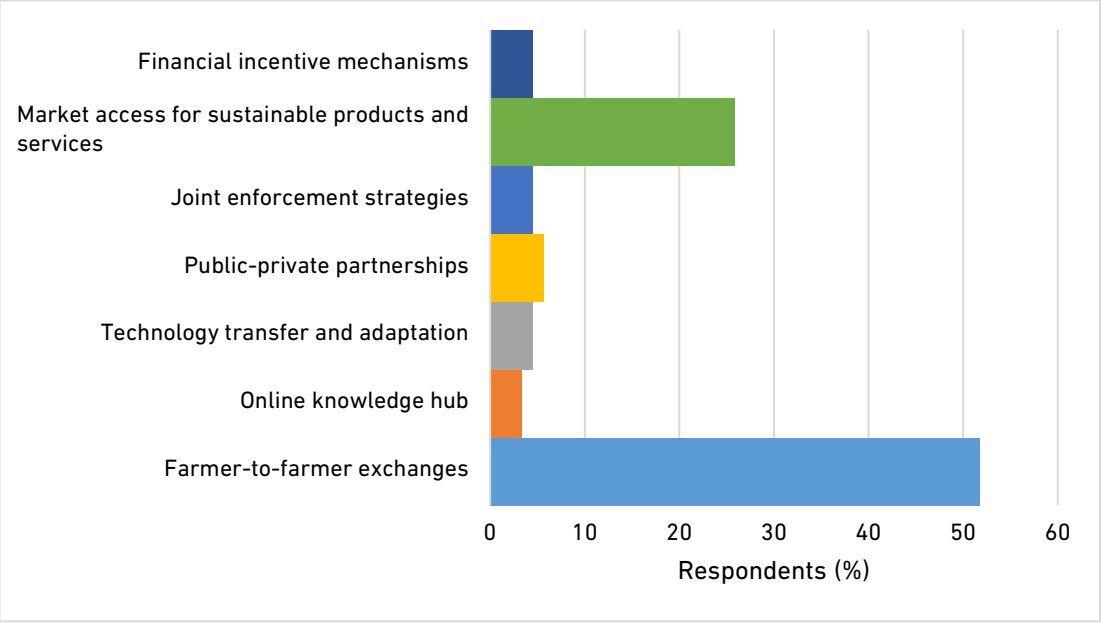
4.3.7.2 Respondents Opinions on Priority Programmes to Scale Up Efforts to Reduce Crop Burning?

Reductions in crop burning could become a scalable programme with sustainable practices and the potential for commercialisation in the future. Our study shows that the first programmes to scale up are farmer-to-farmer exchanges (since farmers are the best ones to share their successes and challenges with their peers) and market access for sustainable products and services (Figure 4.22). In addition, there should be incentives to commercialise products generated from sustainable agricultural practices and eco-friendly innovations to promote better income

generation for farmers and ensure sustainable productivity.

The findings of the study also revealed that the involvement of public–private partnerships could play a crucial role in reducing crop burning by providing market access and financial support and by introducing available and accessible technologies.

Figure 4.22. Respondents' Priorities for Scaling-Up Programmes

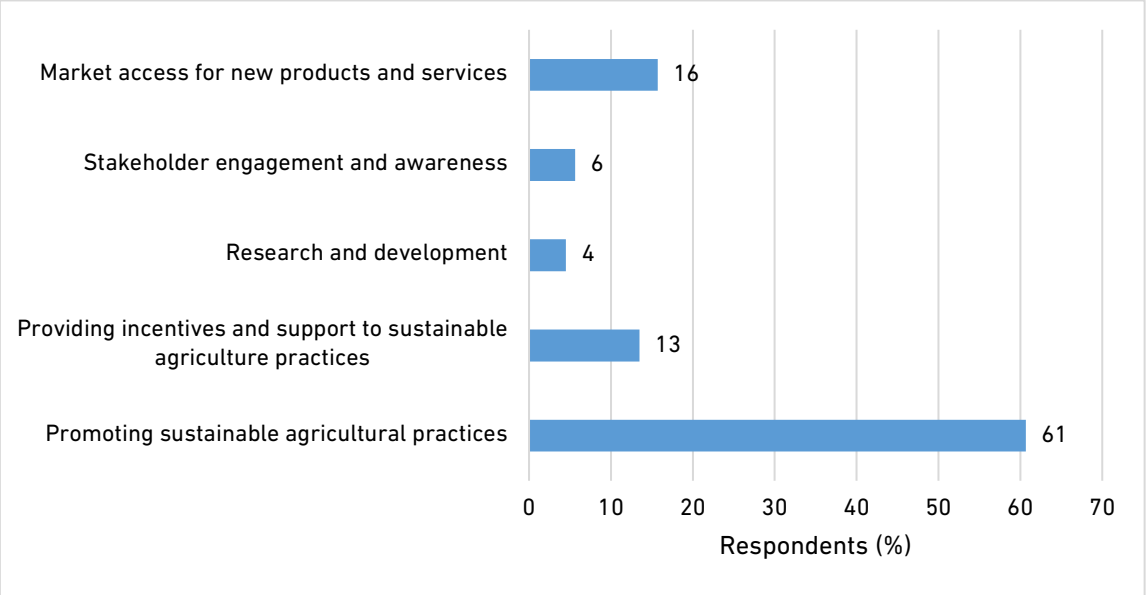


Source: Author's analysis.

4.3.7.3 Respondents Opinions on the Implementation of Integrated Strategies to Promote a Reduction in Crop Burning

Promoting a reduction in crop burning needs suitable integrated strategies for all stakeholders. Figure 4.23 shows that the top integrated strategy chosen was 'Promoting sustainable agriculture practices' (60%). Farmers and respondents in Lao PDR and acknowledged that they had been trained in climate-smart agriculture, good agriculture practices, crop rotation, and an integrated farming system. In addition, concepts of good agricultural practices and climate-smart agriculture enhance sustainable agriculture practices by avoiding crop burning to reduce greenhouse gas emissions. The second strategic priority was to create market access for sustainable products and services. This strategy could help farmers to generate extra income and create jobs in the local communities. The third strategy was to promote financial incentives to enhance sustainable agricultural practices.

Figure 4.23. Respondents' Priorities for Integration Strategies to Promote Reduced Crop Burning



Source: Author's analysis.

4.3.8 Technology

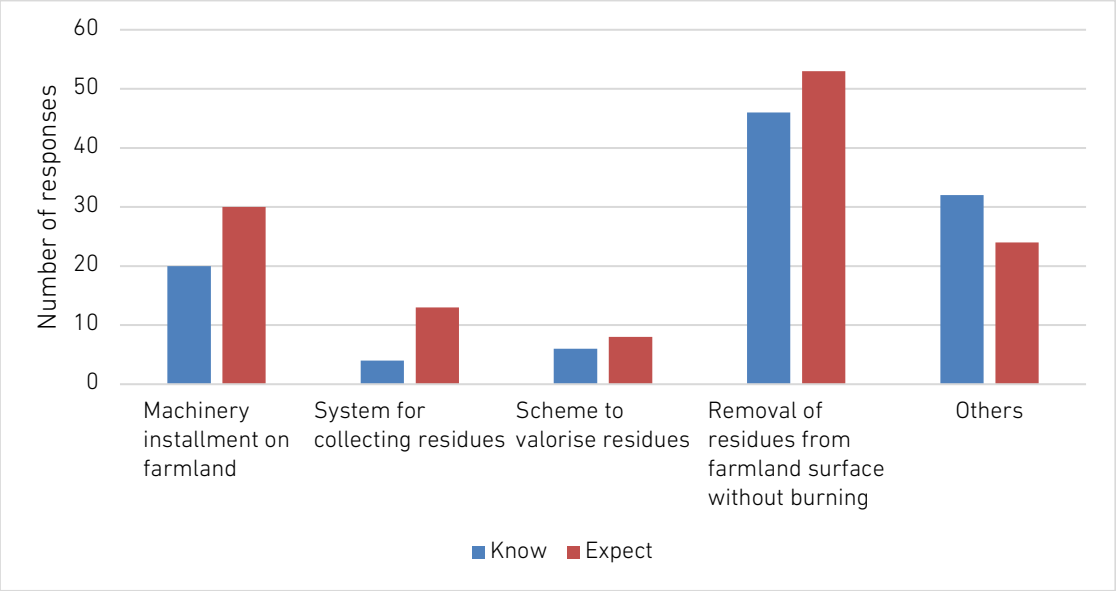
4.3.8.1 Respondents Knowledge of Technologies Already Implemented and Those Expected to be Implemented to Reduce Crop Burning and Use Residues.

Promoting a reduction in crop burning requires a multifaceted approach. Innovative technologies play a key role in developing better systems for agricultural waste management. This study examines current implementation practices and the expectations of farmers regarding reductions in crop burning and the utilisation of crop residues in Lao PDR.

Figure 4.24 shows that a reduction in crop burning could be achieved through the removal of crop residue from the fields. Farmers expressed a strong preference for the installation of machinery on farmland that would enable them to process cassava waste into value-added products, such as compost and biochar. For example, biochar production has been identified as a sustainable solution for reducing agricultural crop residue burning and enhancing environmental protection (Khare et al., 2021).

A key finding was that farmers reported the challenges of collecting agricultural waste or residue from the farms and taking it to crop residue processing and treatment plants. Many farms are in mountainous areas, and transportation is challenging.

Figure 4.24. Respondents' Preferences for Technology to Reduce Crop Burning and Valorise Crop Residue



Source: Author's analysis.

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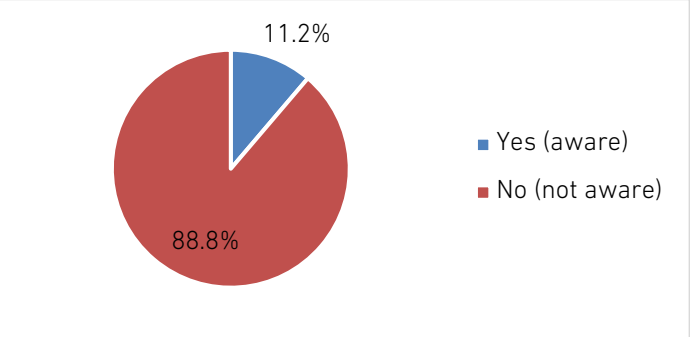
4.3.8.2 Respondents Awareness of the Implementation of New Technology and its Effects

The study also investigated farmers' application of technology that is currently available to them in their regions to manage cassava residues. Figure 4.25 shows that only 11.2% of farmers currently utilise new technology to mitigate cassava burning on their farmland while 88.8% of farmers still burn their agricultural residue. For example, some cassava producers adopt integrated practices by using big tractors to plough cassava leaves and stems directly into their fields, while agrochemical products like herbicides were also used to control weeds due to a lack of access to labour and relevant cassava residue management technology.

Figure 4.25. Respondents' Awareness of Recent Technology and its Effects



For Yes (aware)

- Using big tractors to plough residues into the soil.
- Leave residue in the field, but use herbicides to control weeds

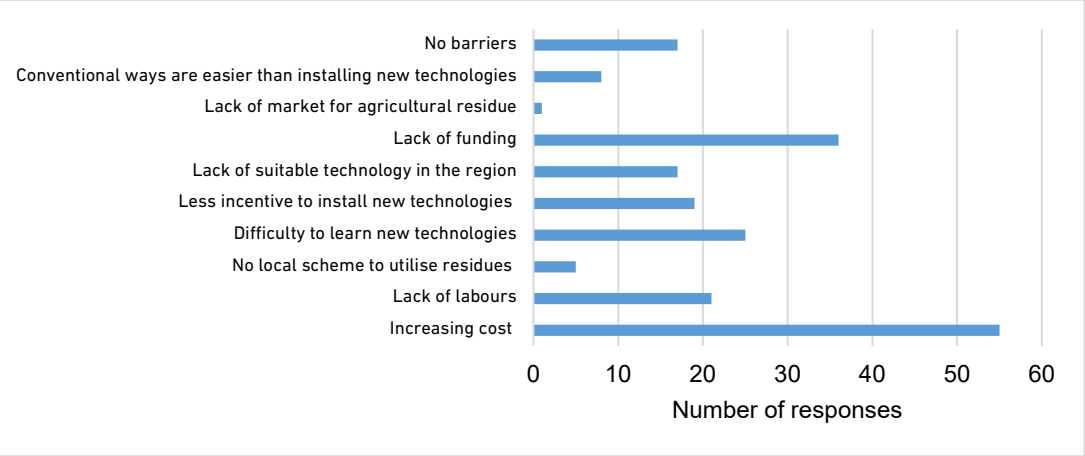
Source: Author's analysis.

4.3.8.3 Respondents Awareness of Barriers to Installing New Technologies to Reduce Crop Burning?

Reducing crop burning can be promoted by introducing new technologies to help farmers mitigate the toxic greenhouse emissions and change to new practices. However, several problems limit farmers' acceptance of the new technologies. The results show that the main barriers are the increasing cost of production, lack of funding, and difficulty of learning new technologies (Figure 4.26).

In addition, there is limited availability of suitable equipment and machinery in the regions. The study also revealed that farmers had limited knowledge about practices to reduce crop burning, while market access for sustainable agricultural practices is underdeveloped in Lao PDR.

Figure 4.26. Barriers to Respondents Installing New Technologies



Source: Author's analysis.

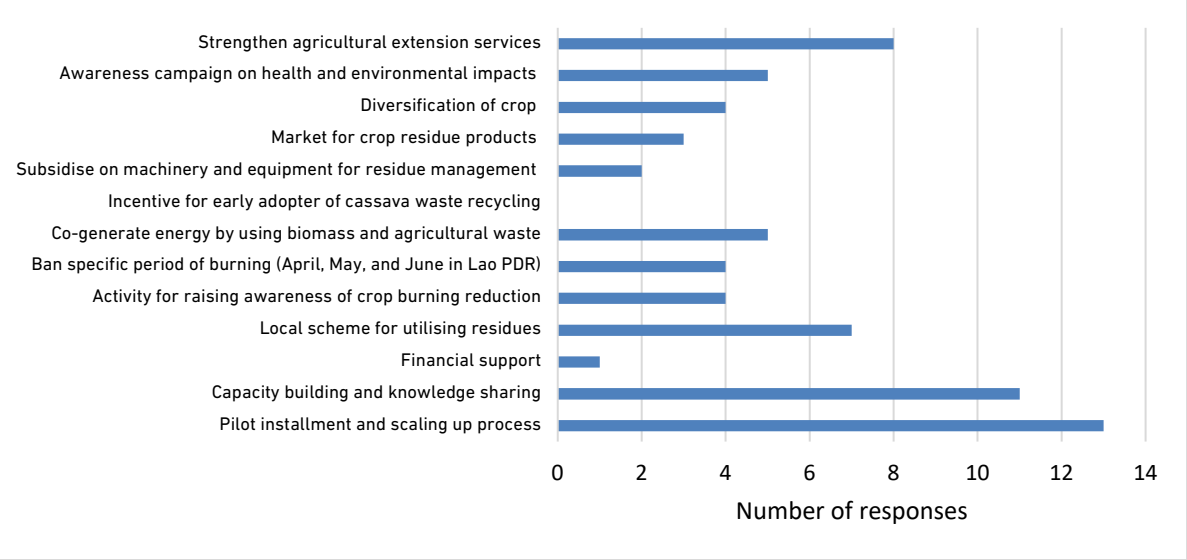
4.3.8.4 Respondents' Solutions to Promote the Implementation of New Technologies

Respondents who identified barriers to technology adoption in Q8.3 of the survey questionnaire were asked about possible solutions to promote the implementation of new technologies to reduce crop burning.

Some early adopters had embraced crop-burning initiatives and promotions in the study areas. However, these farmers also need support and innovative initiatives and suggested possible solutions to reduce crop burning (Figure 4.27). The top three solutions were pilot instalment and scaling-up processes, capacity building and knowledge-sharing and to strengthen agricultural extension services. These groups of farmers wanted to learn more about the new technologies and search for advice from scientists and government extension services.

The second group of proposed solutions were creating a small local scheme for crop residue utilisation, focused on raising awareness about crop-burning reduction and a campaign on health and environmental impacts. Finally, the promotion of energy cogeneration by using biomass and agricultural waste.

Figure 4.27. Respondents' Suggestions to Promote the Implementation of New Technologies



Lao PDR = Lao People's Democratic Republic.
Source: Author's analysis.

4.4 Conclusion and Recommendations

Reducing crop burning in cassava production and promoting sustainable agricultural practices is essential. Cassava stems can be used for vegetative

propagation, making it important to preserve their condition. Residues can be used for composting, animal feed, and biochar. Cassava's ability to grow in marginal soils means that soil health improvements are also very important. It is also vital to provide economically viable alternatives; when farmers can make money from the residue, it will help them promote a reduction in crop burning.

4.4.1 Promote Alternative Residue Management

- Mulching:
  - Use cassava residue as mulch. Chopped cassava residue, such as stems and leaves, can be used as mulch. This helps to maintain soil moisture, suppress weeds, and improve soil fertility, which is important to avoid soil erosion in mountainous areas.
  - Use other materials as mulch. Encourage farmers to use other available organic materials as mulch, like cut grasses. Other vegetative residue around the farm can also be used for composting and returned to the field.
- Composting:
  - Compost cassava residues. This will create nutrient-rich fertiliser. Organic fertilisers are very important to maintain good soil conditions for cassava production in the future, especially for farmers who produce cassava as a monocropping system.
  - Provide training and resources. Providing training and resources on effective composting techniques and sustainable agriculture practice, good agricultural practices and climate-smart agriculture enhances local capacity and promotes a reduction in crop burning.
- Incorporation into Soil and Biochar Production:
  - Promote farming systems and machinery. Promoting farming systems and machinery will encourage farmers to plough crop residues directly into the soil. This practice enriches the soil with organic matter.
  - Encourage processing stem residue into biochar. Farmers can be encouraged to process stem residue into biochar for commercialisation which can then be returned to the soil to improve its fertility.

4.4.2 Improve Soil Health

- Crop Rotation. Cassava crops can be rotated with other leguminous crops to improve soil fertility and reduce the need for burning. This is the best practices to avoid soil erosion and loss of biomass, maintain cassava productivity, and limit pest and diseases in cassava plantations.

- Intercrop cassava. Intercrop cassava with other crops to cover the soil and reduce weed growth, minimising the need for crop burning. When the cassava is young, other crop can be introduced to avoid soil exposure to the sun and heat.

4.4.3 Provide Education and Training

- Conduct awareness campaigns. Awareness campaigns can educate farmers about the harmful effects of crop burning on the environment and human health.
- Provide training Training can be provided on sustainable agricultural practices, climate-smart agriculture, good agricultural practices, alternative residue management techniques, composting, integrated pest management, and soil conservation.
- Establish demonstration farms. These can showcase the benefits of sustainable cassava production practices.

4.4.4 Strengthen Policy and Incentives:

- Use regulations to restrict crop burning. Implement and enforce regulations to restrict crop burning from local community practices. Support campaigns and capacity building on sustainable agricultural practices and their positive impacts for all on health and the environment.
- Provide financial incentives or subsidies. Financial incentives or subsidies can be provided to farmers who adopt sustainable residue management practices especially early adaptive farmers and farmer groups.
- Offer access to affordable machinery. Affordable machinery for residue processing could include creating transportation and collection mechanisms and funding small biochar schemes to create a market for sustainable agricultural products and a carbon credit market.

4.4.5 Explore Bioenergy Options:

- Investigate biogas production. Investigate the potential for using cassava residues for biogas production. This practice exists for starch waste treatment plants, should be explored for cassava residues, using biofuel production as a sustainable alternative to agricultural waste burning.

References

Association of Southeast Asian Nations (ASEAN) (2023), *ASEAN Regional Guidelines for Sustainable Agriculture in ASEAN*. Jakarta: ASEAN Secretariat. https://asean.org/book/asean-regional-guidelines-for-sustainable-agriculture-in-asean-developing-food-security-and-food-productivity-in-asean-with-sustainable-and-circular-agriculture/

———. (2024), *ASEAN Guidelines on the Reduction of Crop Burning*. Jakarta: ASEAN Secretariat. https://asean.org/book/asean-guidelines-on-the-reduction-of-crop-burning/

Chen, J., Y. Gong, S. Wang, B. Guan, J. Balkovic, and F. Kraxner (2019), 'To Burn or Retain Crop Residues on Croplands? An Integrated Analysis of Crop Residue Management in China'. *Science of the Total Environment*, 662, pp.141–50. https://doi.org/10.1016/j.scitotenv.2019.01.150

Khare, P., Y. Deshmukh, V. Yadav, V. Pandey, A. Singh, and K. Verma (2021), 'Biochar Production: A Sustainable Solution for Crop Residue Burning and Related Environmental Issues'. *Environmental Progress & Sustainable Energy*, 40(2), e13529. https://doi.org/10.1002/ep.13529

Lin, M. and T. Begho (2022), 'Crop Residue Burning in South Asia: A Review of the Scale, Effect, and Solutions with a Focus on Reducing Reactive Nitrogen Losses', *Journal of Environmental Management*, 314, pp.115104–11. https://doi.org/10.1016/j.jenvman.2022.115104

Mathur, R. and V.K. Srivastava (2019), 'Crop Residue Burning: Effects on Environment: Challenges, Technologies and Solutions', in N. Shurpali, A. Agarwal, and V. Srivastava (eds), *Greenhouse Gas Emissions. Energy, Environment, and Sustainability.* Singapore: Springer. https://doi.org/10.1007/978-981-13-3272-2_9

Singh, D. et al. (2022), 'Crop Residue Burning and Its Relationship between Health, Agriculture Value Addition, and Regional Finance'. *Atmosphere*, 13(9), pp.1405–21. https://doi.org/10.3390/atmos13091405

Vadrevu, K.P., K. Lasko, L. Giglio, W. Schroeder, S. Biswas, and C. Justice (2019), 'Trends in Vegetation Fires in South and Southeast Asian Countries', *Scientific Reports*, 9(1), p. 7422. https://doi.org/10.1038/s41598-019-43940-x

Chapter 5
Case Study on Reducing Crop Burning in ASEAN Member States: Rice Straw in Thailand

Nittaya Cha-un

5.1 Introduction

5.1.1 Outline of the Survey

As part of the *ASEAN Guidelines for the Reduction of Crop Burning* adopted at the 46th AMAF in October 2024, country case studies on specific crops are required to promote the implementation of the guidelines. This chapter sets out a comprehensive examination of current crop residue management practices in Thailand, including a. literature review and interview surveys for the targeted crop – rice.

Current strategies for reducing rice straw burning in Thailand such as policies and initiatives, financial systems, research and development, and opportunities for capacity building are summarised, based on previous literature and studies.

An interview survey was conducted to identify the issues related to rice residue management and potential solutions to reduce rice crop burning. The questionnaire content for the interview was prepared by the Economic Research Institute for ASEAN and East Asia (ERIA) and subsequently refined by the report author and ERIA.

The study involved approximately 70 stakeholders from the value chain in Thailand, including rice farmers. The findings are organised into four categories: (i) policies and initiatives, (ii) foundational systems, (iii) technologies and techniques, and (iv) capacity building. The challenges and potential solutions for each category are analysed at the farm and national level.

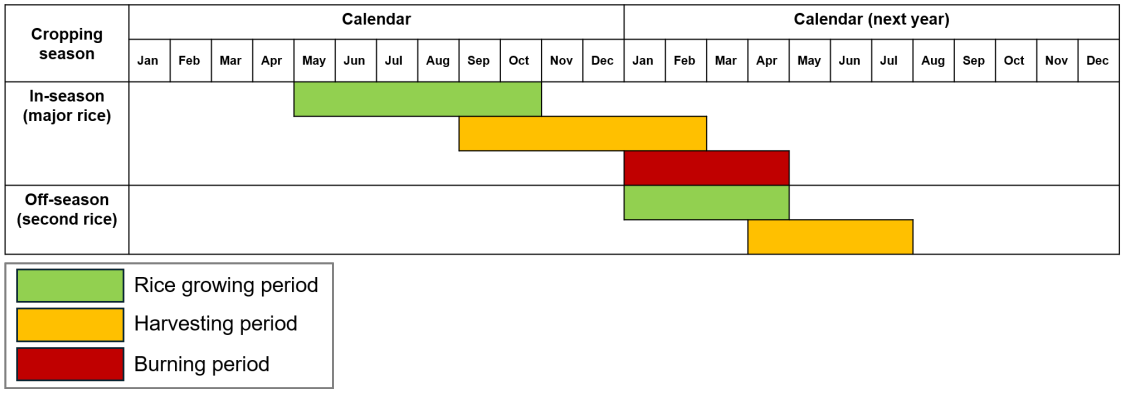
5.2 Rice Cultivation and Rice Residue Management in Thailand

5.2.1 Rice Cultivation

There are two types of rice cultivation in Thailand: major rice cultivation and second rice cultivation (Figure 5.1). The term major rice denotes the 'in-season rice,' which is the conventional practice of cultivating rice during the rainy season. The growing season starts in May and extends until October, ending with a harvest period that

terminates in February. Second rice denotes the cultivation of rice during the dry season, commonly referred to as 'off-season rice.' Cultivation of these crops may commence as early as January, with harvesting concluding by April at the latest. This phenomenon is prevalent in areas with specialised irrigation systems, particularly in central Thailand. The rice growing area in Thailand is approximately 65 million rai (10.4 million hectares)[3] and after harvest, it produces an average of 25.45 million tonnes of rice straw per year. From this, approximately 16.9 million tonnes of rice stubble remains in the rice fields (Rice Department, 2016; and OAE, 2023). Consequently, rice fields produce the highest volume of agricultural residue in comparison to other crops, and these residues are burned year-round.

Figure 5.1. Crop Calendar for Planting, Harvesting, and Open Burning of Rice in Fields



Source: Modified from Rice Department (2016) and OAE (2023).

The Table 5.1 presents major rice sector data in Thailand from 2014 to 2023, highlighting trends in planted areas, harvested areas, production, yields, farm gate prices, and the value of production (OAE, 2023). Both the planted and harvested areas show a slight decrease over the years. While there are some fluctuations, the overall trend suggests a decline. The production and yield figures also fluctuate but remain relatively stable throughout the period. There are minor increases and decreases, but no significant trend. The price that farmers receive for their products show an overall increasing trend. There are some minor drops, but the general direction is upward. The value of production shows a noticeable increase, especially in 2022 and 2023. This increase is likely to be driven by the rising farm gate prices, despite the slight decreases in planted and harvested areas.

[3] Rai is a traditional unit of land area in Thailand, equal to 1,600 square metres (0.16 hectares or approximately 0.395 acres).

Table 5.1. Thailand's Rice Production, Yield, Farm-Gate Prices, and Production Value, 2014–2023

Year	Planted area (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tonnes)	Yield (kg/rai)	Farm gate price (THB/tonne)	Value of production (THB million)
2014	60,791	58,247	26,270	451	9,130	239,845
2015	58,063	55,096	24,312	441	9,070	220,506
2016	58,645	56,546	25,236	446	8,073	203,733
2017	59,221	54,963	24,934	454	8,817	219,846
2018	59,981	55,627	25,178	453	9,711	244,513
2019	61,197	54,108	24,064	445	10,099	243,016
2020	62,438	60,094	26,424	440	8,986	237,457
2021	63,013	60,261	26,807	445	8,362	224,146
2022	62,838	59,492	26,712	449	10,548	281,758
2023	61,928	58,412	25,569	438	11,360	290,464

kg = kilogram, THB = Thai baht.
Note: Rai is an area unit of Thailand, 1 rai = 1600 m^2, 0.16 rai = 1 ha, 1 ha = 6.25 rai, $^{1/}$ paddy
Source: OAE (2023).

Table 5.2 provides data on second rice crops in Thailand from 2015 to 2024. The table includes information on planted areas, harvested areas, production, yields, farm gate prices, and value of production (OAE, 2023). Both the planted and harvested areas show fluctuations over the years, with notable decreases in 2016 and increases in 2017 and 2018. Production and yield figures also fluctuate, with the yield remaining relatively stable between 612 and 656 kilograms per rai. The farm gate price shows a general increasing trend, with significant jumps in 2020 and 2023. The value of production displays an upward trend, particularly notable in 2022 and 2023, driven by the increased farm gate prices.

Table 5.2. Thailand's Second Rice: Area, Production, Yield, Farm-Gate Price, and Production Value

Year	Planted area (1,000 rais)	Harvested area (1,000 rais)	Production[1/](1,000 tonnes)	Yield[1/] (kg/rai)	Farm gate price (THB/tonne)	Value of production (THB million)
2015	8,461	8,409	5,347	636	7,747	41,423
2016	5,138	5,080	3,109	612	8,170	25,404
2017	10,457	10,403	6,621	636	7,779	51,504
2018	12,067	12,035	7,965	662	7,812	62,219
2019	10,995	10,922	7,170	656	7,790	55,856
2020	7,342	7,221	4,554	631	9,170	41,758
2021	8,343	8,307	5,310	639	8,641	45,888
2022	9,547	9,518	6,171	648	8,754	54,023
2023	10,606	10,581[p]	6,918[p]	654[p]	10,172	70,368
2024	9,708	9,669[f]	6,238[f]	645[f]	11,772[2/]	73,438

kg = kilogram; ha = hectare; m^2 = square metre; THB = Thai baht.
Note: Rai is an area unit of Thailand, 1 rai = 1600 m^2, 0.16 rai = 1 ha, 1 ha = 6.25 rai.
[p] preliminary data, [f] forecasting data, [1/] paddy, [2/] Price in 2024 is the average price of Jan and Feb.
Source: OAE (2023).

5.2.2 Rice Residue Management

Thailand produces a lot of agricultural residues. After harvesting crops, rice straw and stubble are rice harvest residue. Farmers sometimes burn rice straw and stubble to prepare the land for the following crop. Open burning of rice residues is one of the most significant sources of air pollution in Thailand.

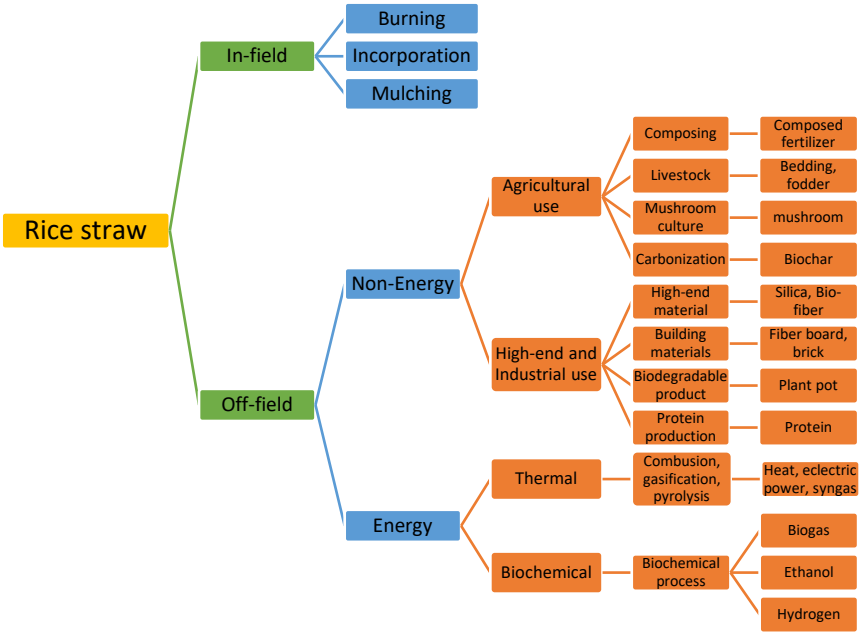
Open-field burning of rice straw has been seen as an easy method for the elimination of large quantities of biomass as well as for the management of weed populations and the control of pests and diseases (Ponnamperuma, 1984). Nevertheless, research shows that the negative effects of burning offset any advantages. Negative consequences include nutrient loss, a decline in soil organic matter, and less abundance of beneficial soil biota (Mandal et al., 2004).

Both methane, ranging from 0.7–4.1 grams of methane per kilogram of dry rice straw and nitrous oxide, ranging from 0.019–0.057 grams of per kilo, are emitted

from burning rice straw in agricultural fields. Other gaseous pollutants including sulphur dioxide, nitrogen oxides, hydrogen chloride, and to some degree, dioxins and furans also result from this process (Kim Oanh et al., 2011; Jenkins et al. 2003). One major source of aerosol particles including both fine particles (PM2.5) and large dust particles (PM10) is the burning of rice straw (Chang, Liu, and Tseng, 2013). This phenomenon has major effects on the earth's radiation budget as well as regional air quality (Engling, Lee, and Tsai, 2009). Due to these environmental risks, open-field straw burning has been banned or subject to strict rules in many areas in Thailand.

Figure 5.2 shows a flowchart detailing various management and utilisation alternatives for rice straw. The chart is divided into two categories: in-field and off-field. In-field management options for rice straw, including open-field burning and incorporation, may have positive and negative impacts on the efficiency and sustainability of rice production. Management of rice straw influences the energy and nutrient balance, the efficiency of fertiliser inputs, emissions of methane and atmospheric pollutants, as well as the risks of pests and diseases in rice agro-ecosystems. Transformations in rice agro-ecosystems, driven by changing social, climatic, environmental, and economic conditions, particularly in Asia, are likely to impact rice farmers' strategies for in-field residue management. Off-field rice straw management involves the removal of rice straw from the field for alternative uses. In addition to its application in bioenergy production, rice straw serves various non-energy purposes, including mushroom cultivation, cattle feed, mulching for other crops, and the production of high-end industrial materials utilising the silica present in rice straw (IRRI, 2019). The options presented offer diverse methods for managing and utilising rice straw, with the objectives of minimising environmental impact and enhancing economic value.

Figure 5.2. Rice Straw Management and Utilisation Alternatives



Source: Author's modification from Gummert (2024).

5.2.3 Regulations Related to Field Open Burning in Thailand

Regulations related to field open burning in Thailand are governed by various laws and regulations aimed at environmental protection, air quality control, and agricultural practices. The burning of agricultural residue is an activity that must comply with laws related to natural resource and environmental management in Thailand (Table 5.3).

Table 5.3. Key Regulations and Standards Relevant to Open Field Burning in Thailand

Regulations	Purpose
Environmental Protection and Promotion Act B.E. 2535 (1992)	This overarching legislation addresses environmental protection and pollution control, including provisions related to open burning and its impact on air quality.
Clean Air Act B.E. 2535 (1992)	This Act focuses on the control and prevention of air pollution, encompassing regulations related to emissions and open burning activities that may contribute to air pollution.
Ministerial Regulation on the Control of Open Burning B.E. 2555 (2012)	Issued under the authority of the Ministry of Natural Resources and Environment, this regulation provides specific guidelines and controls for open burning

Regulations	Purpose
	activities, including those related to agricultural practices.
Thai Agricultural Standard TAS 4408-2022 for Sustainable Rice	*TAS 4408-2022* aims to promote environmentally friendly and sustainable practices in rice production. This standard emphasises a reduction in environmental impacts associated with traditional rice production practices, including straw burning, which contributes to air pollution and greenhouse gas emissions.
Draft Climate Change Act	Thailand is drafting the *Climate Change Act* and expects it to be implemented by 2025. This legislation is meant to support the country's goal of achieving net-zero emissions by 2065. The Act also aims to reduce greenhouse gas emissions across various sectors, including agriculture. Since straw burning contributes to air pollutants and greenhouse gas emissions, this Act supports measures that encourage sustainable agricultural practices.
Royal Decree on Air Quality Management in Residential Areas B.E. 2553 (2010)	Although primarily focusing on residential areas, this Royal Decree may include standards and regulations related to air quality management, indirectly impacting open burning practices.
Local regulations and bylaws	Provinces, municipalities, or local authorities may have specific regulations or bylaws addressing open burning practices. Local ordinances can vary, and it is essential to consider regional variations in regulations.

Source: Author's analysis, 2024.

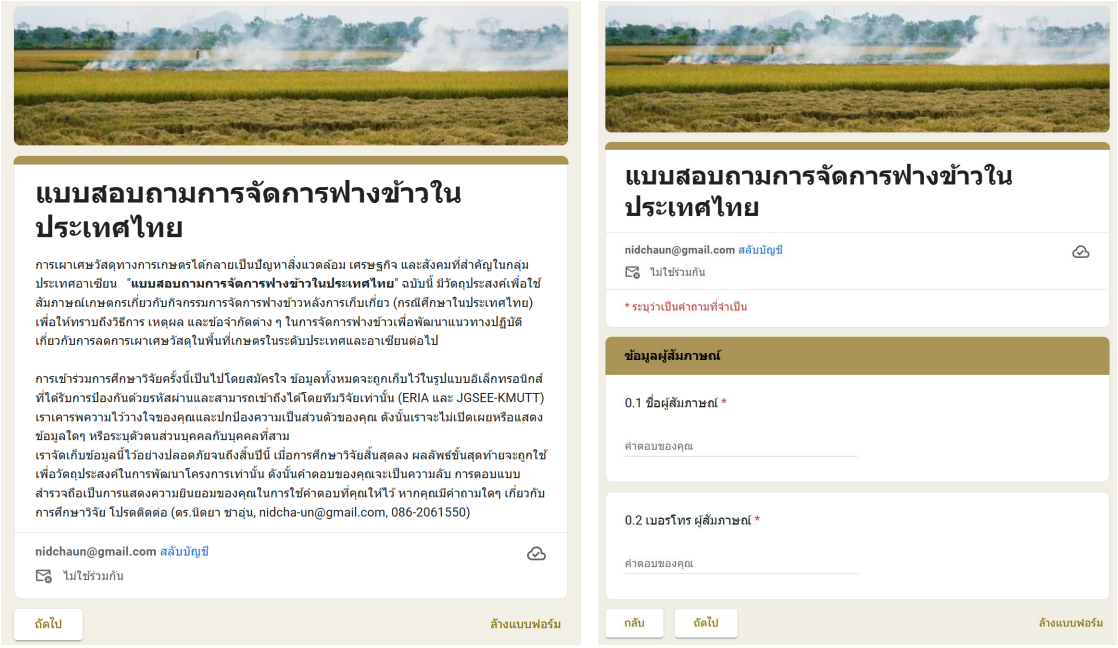
However, there are reasons why farmers in Thailand may continue to burn rice straw, based on local conditions, agricultural practices, and economic considerations. Efforts are being made to promote sustainable cultivation practices that do not involve burning both globally, and in Thailand. These efforts involve government regulations, incentives, and educational campaigns to raise awareness about environmentally friendly alternatives to open burning, such as green harvesting, mechanical harvesting without burning, and effective residue management techniques. Encouraging the adoption of these practices is crucial to mitigating the negative environmental impacts associated with field open burning.

5.3 Field Survey and Data Collection

To facilitate the field survey, we translated the questionnaire into Thai and

converted it into an online survey using Google Forms (Figure 5.3). The questionnaire was divided into eight sections: (i) respondent identity, (ii) farming status, (iii) opinions on crop burning, (iv) activities for crop-burning reduction, (v) crop-burning reduction policies, (vi) capacity building and knowledge-sharing, (vii) involving stakeholders, and (viii) technologies. The full English version of the questionnaire is shown in the Appendix.

Figure 5.3 Online Survey Tool (Thai Version) Using Google Forms



Source: Author's image.

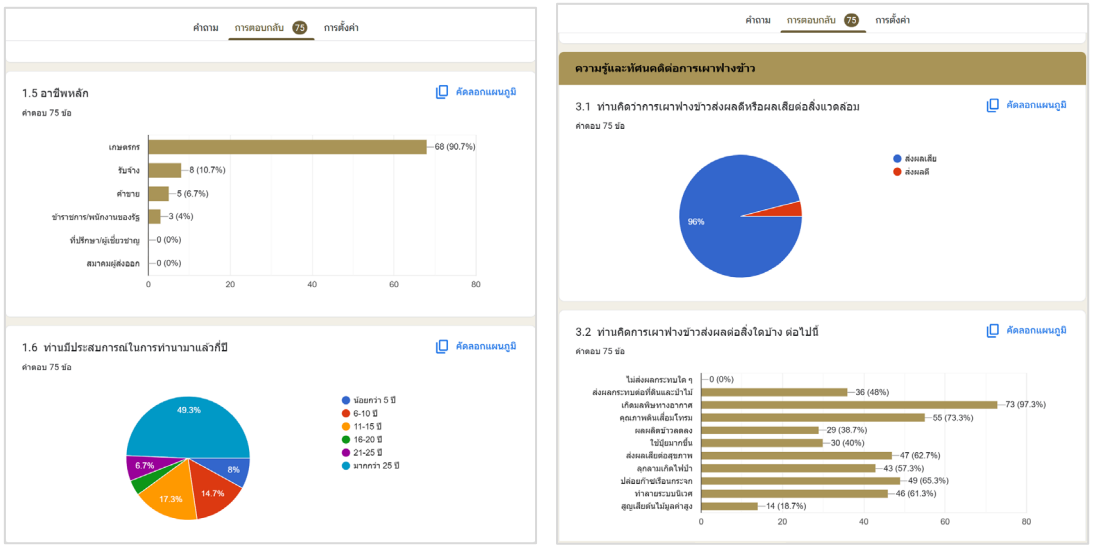
Data collection was conducted across eight provinces within the Lower Northern and Northeastern regions of Thailand, specifically, Uttaradit, Phitsanulok, Phetchabun, Sukhothai, Kamphaeng Phet, Amnat Charoen, Khon Kaen, and Ubon Ratchathani. In the target area, the collection of data was conducted by visiting the field and randomly interviewing farmers (Figure 5.4). Some farmers were also sent the link to an online survey for data recording.

Figure 5.4 Field Visits and Interviews with Farmers

Source: Author's image.

The collected data were initially analysed statistically using the Google Form platform (Figure 5.5). Statistical analyses, including the calculation of mean values, standard deviations, and other descriptive statistics, were performed using Microsoft Excel.

Figure 5.5 Survey Results on the Google Forms Platform



Source: Author's image.

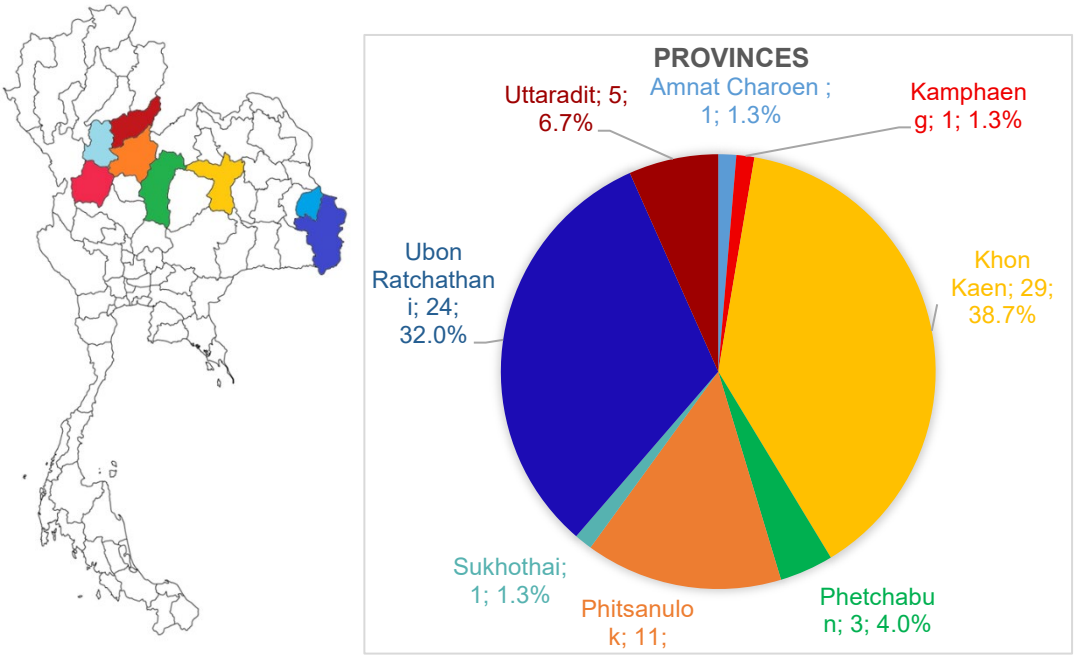
5.4 Results and Discussion

5.4.1 PART I: Respondent Identity

The results of the survey were obtained from 75 farmers in eight provinces in the Lower Northern and Northern regions of Thailand (Figure 5.6), including

- Uttaradit (5 farmers)
- Phitsanulok (11 farmers)
- Phetchabun (3 farmers)
- Sukhothai (1 farmer)
- Kamphaeng Phet (1 farmer)
- Amnat Charoen (1 farmer)
- Khon Kaen (29 farmers)
- Ubon Ratchathani (24 farmers)

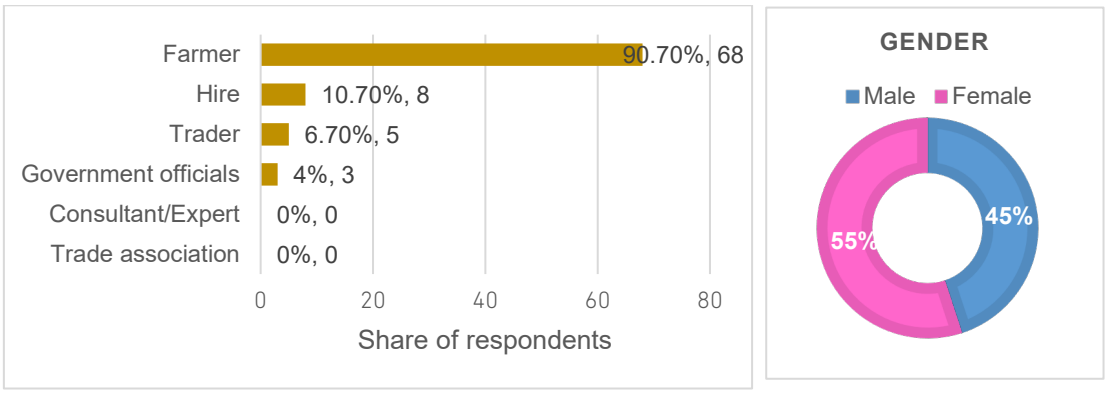
Figure 5.6. The Target Sites for Data Collection and the Numbers of Respondents



Source: Author's analysis, 2024.

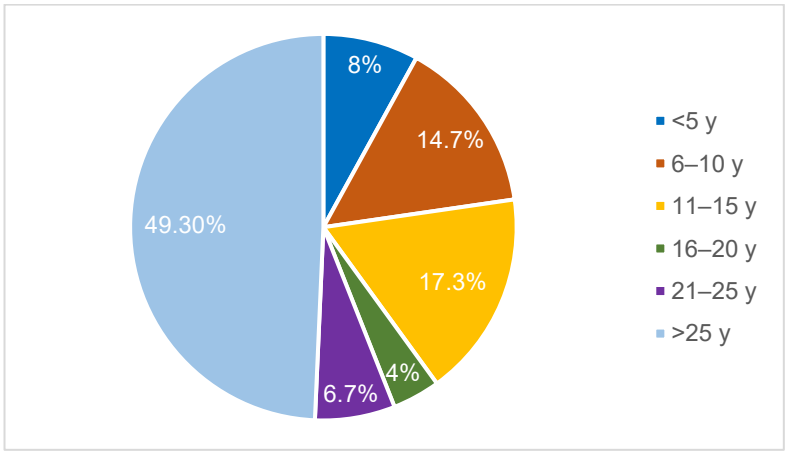
A total of 90.7% of the participants in the interviews identified as farmers, with a gender distribution of 45.0% male and 55.0% female (Figure 5.7). Nearly half (49.3%) of the farmers have over 25 years of experience in rice farming (Figure 5.8).

Figure 5.7 Gender Distribution and Occupation of Respondents



Source: Author's analysis, 2024.

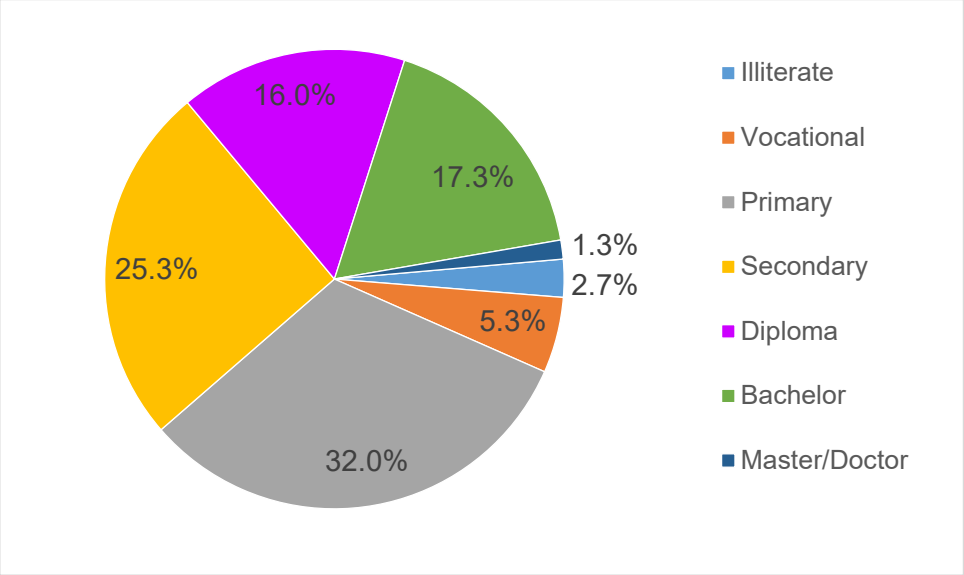
Figure 5.8 Farmers' Years of Rice Farming Experience



Source: Author's analysis.

Most farmers had household sizes of three or four members, representing 42.7% of total respondents. The next largest group comprised 28.0%, consisting of five to six members; followed by 21.3%, comprising one to two household members; and 8.0%, comprising more than six members. An average of two family members per household worked on the farms. Farmers have rice cultivation areas ranging from 2–100 rai, with an average of 18 rai per household, which is consistent with the report by the Agricultural Land Reform Office (2023) that reported the average agricultural landholding size of Thai farmers as 20 rai per household. Farmers are educated to primary level (32.0%) and secondary level (25.3%) (Figure 5.9).

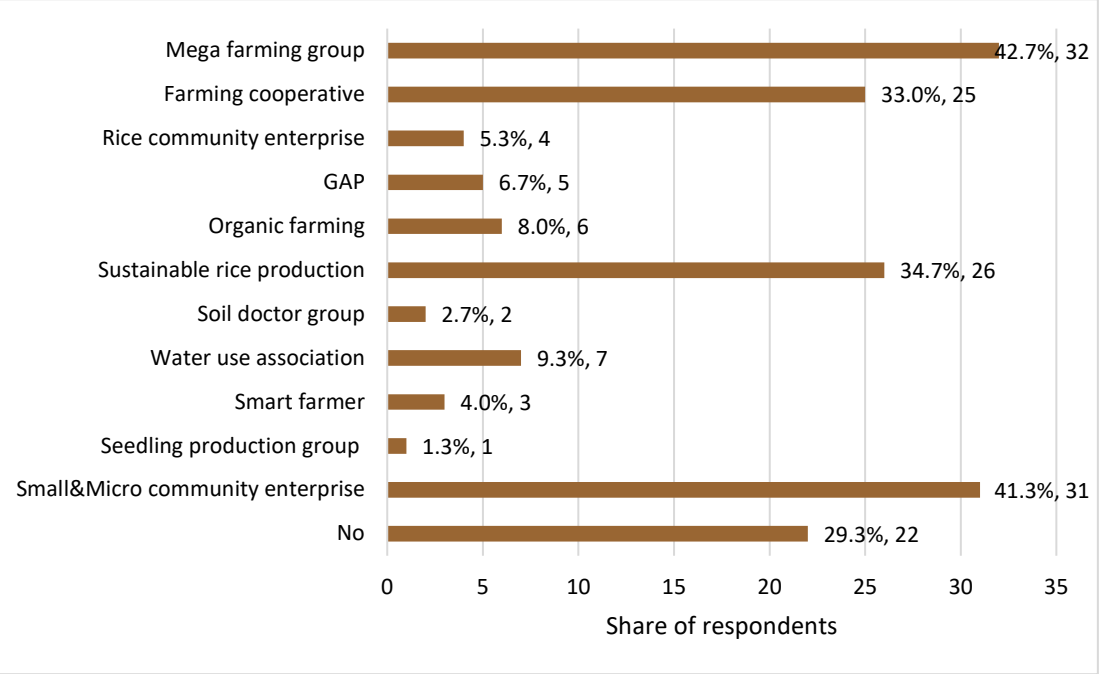
Figure 5.9 Farmers' Level of Education



Source: Author's analysis.

Figure 5.10 shows the membership distribution amongst various farmer associations. Mega Farming Group (42.7%) and Small & Micro Community Enterprise (41.3%) have the most members, showing their popularity and reach amongst farmers. Sustainable Rice Production (34.7%) and Farming Cooperative (33.3%) have large memberships, indicating a strong emphasis on sustainable farming practices and co-operative farming. The Rice Community Enterprise, Good Agricultural Practices, Organic Farming, and the Water User Association all have moderate memberships. A significant proportion of farmers (29.3%) are unaffiliated with any association, indicating potential areas for outreach and engagement. The data show that membership levels vary amongst farmers' associations, with some groups being more popular than others. It provides insight into the focus areas and reach of these associations within the farming community.

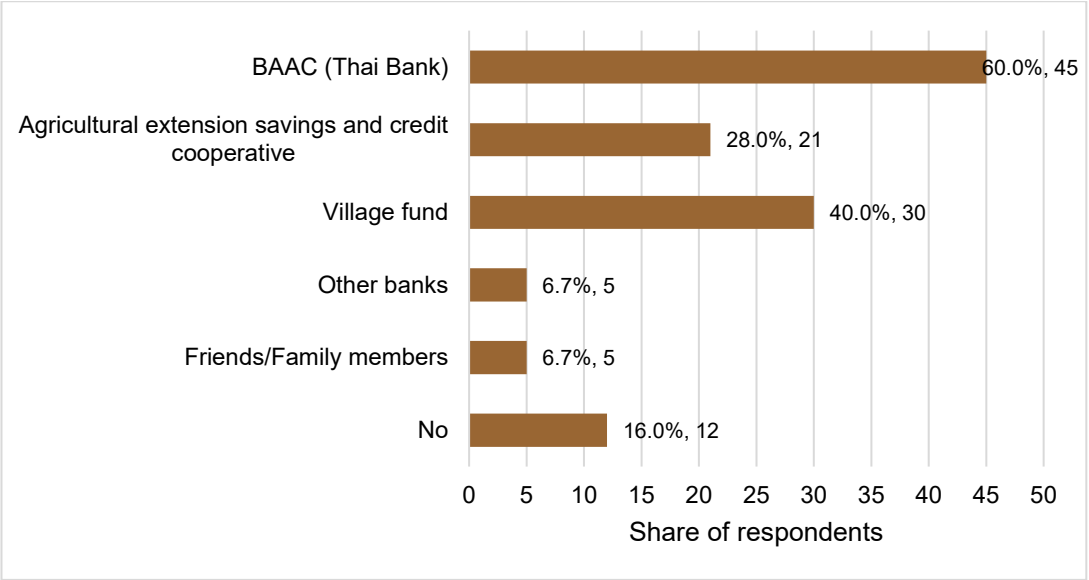
Figure 5.10 Respondents' Membership of Farmers' Associations



GAP = Good Agricultural Practices.
Source: Author's, 2024.

Figure 5.11 shows the data regarding the sources of credit and financial transactions utilised by farmers. The Bank for Agriculture and Agricultural Cooperatives stands out as the leading financing source for farmers, with a significant 60% preference rate. The Village Fund significantly contributes to credit provision, accounting for 40% of the total. Agricultural Extension Savings and Credit Cooperative represent a significant avenue for financial assistance to farmers, accounting for 28%. Nonetheless, 16% of a significant portion of farmers do not utilise any credit source.

Figure 5.11 Respondents' Sources of Credit and Financial Transactions



BAAC = Bank for Agriculture and Agricultural Cooperatives.
Source: Author's analysis.

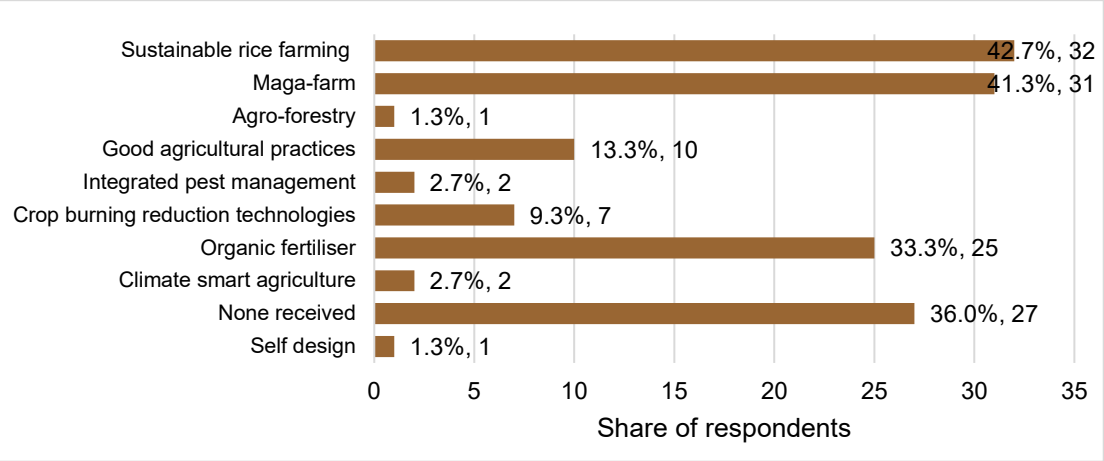
5.4.2 PART II: Current Status of Rice Cultivation in Thailand

During the wet season rice cultivation, farmers in the Lower Northern region, particularly in Phitsanulok, Kamphaeng Phet, Uttaradit, Sukhothai, and Phetchabun, prefer the cultivation of non-photoperiod-sensitive rice varieties, such as RD13, RD41, RD85, RD49 (where "RD" denotes rice varieties released by the Thai Rice Department), Pathumthani 2, Phitsanulok 2, and San Pah Tawng 2. Conversely, farmers in the Northeastern region typically cultivate photoperiod-sensitive varieties. In Khon Kaen province, the prevalent sticky rice variety is RD6, whereas in Ubon Ratchathani and Amnat Charoen, Khao Dawk Mali, 105 is preferred. In the dry season rice crop, most of the cultivation occurs in the Lower Northern region, where irrigation water is available. A diverse selection of non-photoperiod-sensitive cultivars is cultivated, including RD41, RJ33, RD9, RD13, RD10, RD85, Pathumthani 1, and San Pah Tawng 1. In contrast, in the Northeastern provinces of Khon Kaen, Ubon Ratchathani, and Amnat Charoen, where rice fields predominantly depend on rainfall (rainfed area), dry season rice cultivation is limited.

Figure 5.12, illustrating extension services and support received by farmers showed a diverse range of assistance with significant concentration in key areas. A substantial proportion of farmers benefit from sustainable rice farming (42.7%) and Maga-Farm initiatives (41.3%), while climate-smart agriculture support is also important at 33.3%. More established approaches, like good agricultural practices and crop-burning reduction technologies, account for 13.3% and 9.3%, respectively, with very minimal engagement in areas such as agroforestry, integrated pest

management, organic fertiliser use, and self-designed support (each ranging between 1.3% and 2.7%). Notably, 36.0% of farmers reported receiving no support at all, indicating a considerable gap in outreach that could be addressed to enhance overall farm productivity and resilience.

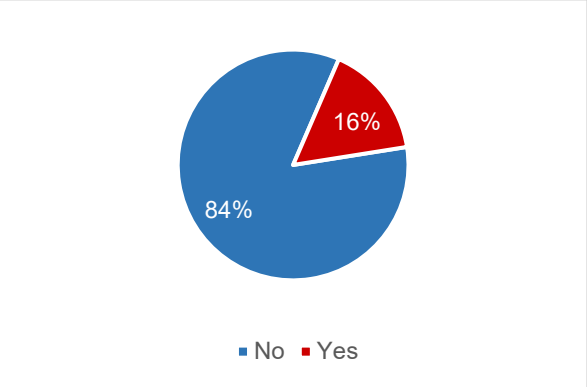
Figure 5.12 Extension Services and Support Received by Respondents



Source: Author's analysis.

The survey on support for rice straw management technologies revealed that 84% of farmers had never received any support. In contrast, only 16% of farmers had received assistance, and even then, it was provided only one or two times per year (Figure 5.13).

Figure 5.13 Respondents Receiving Extension Services Related to Crop-Burning Reduction Technologies



For No

- 84% of farmers have never received any services

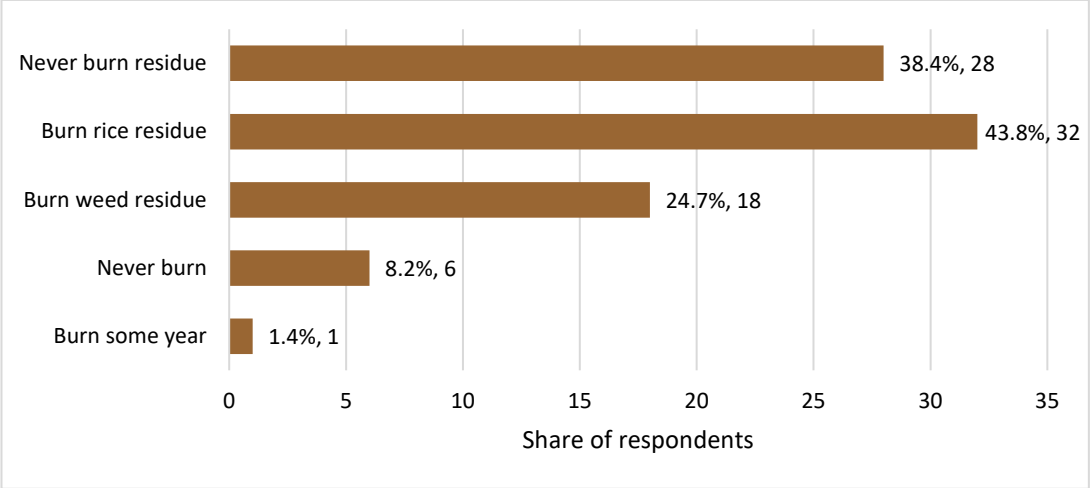
For Yes

- Received 1–2 times per year

Source: Author's analysis.

Figure 5.14 illustrates the experiences of farmers regarding crop residue burning. Most notably, 43.8% of the respondents (32 farmers) engage in burning rice residue, making it the dominant practice, while a substantial 38.4% (28 farmers) report not burning any residue at all a sign that a significant number of farmers are either using alternative residue management techniques or avoiding burning due to policy, cost, or environmental concerns. Additionally, 24.7% (18 farmers) burn weed residue, indicating that for some, burning serves as an agronomic tool for weed control. A smaller subset 8.2% (6 farmers) and 1.4% (1 farmer) follow other forms of residue management, either completely avoiding burning or doing so selectively in certain years. Furthermore, if farmers have to manage straw without burning it, they will have an additional cost of B50 baht–B2,500 per rai.[4] This data is significant as it provides insights into the common practices amongst farmers concerning crop residue management, indicating that a notable percentage of farmers turn to burning rice residue, which may have implications for environmental and agricultural policies.

Figure 5.14 Respondents' Experiences of Crop Residue Burning



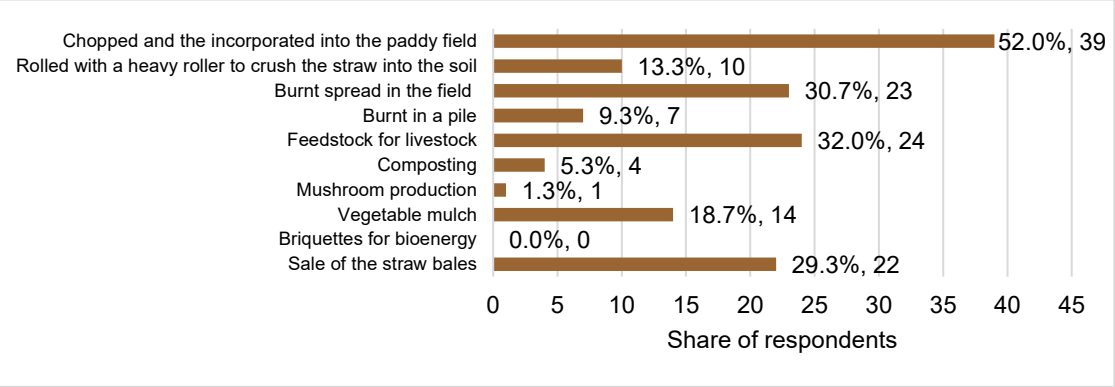
Source: Author's analysis.

Figure 5.15 illustrates the various methods farmers use to manage rice straw during the wet season. The most common method, practised by 52.0% of farmers, is chopping the straw and incorporating it into the paddy field. Other significant methods include using the straw as feedstock for livestock (32.0%), burning the straw spread in the field (30.7%), and selling the straw bales (29.3%). Less common practices are using vegetative mulch (18.7%), rolling with a heavy roller to crush

[4] B = Baht.

the straw into the soil (13.3%), burning in a pile (9.3%), composting (5.3%), and mushroom production (1.3%). Notably, no farmers reported using the straw for briquettes for bioenergy. This data provides insights into the diversity of straw management practices amongst farmers, highlighting both traditional and innovative approaches, and underscores the potential for targeted interventions to promote more sustainable methods.

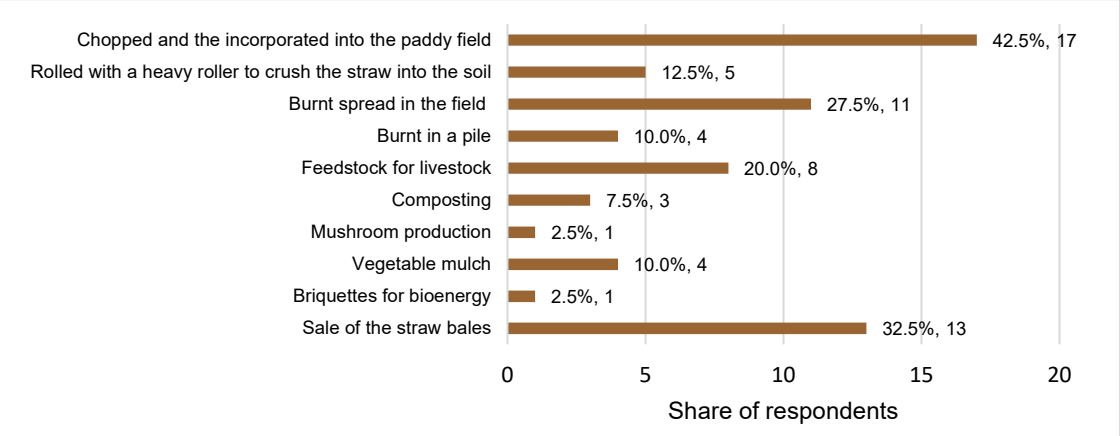
Figure 5.15 Options Respondents Use to Manage Rice Straw in the Wet Season



Source: Author's analysis.

Figure 5.16 presents various rice straw management methods adopted by farmers during the dry season, highlighting the diversity of approaches. The most prevalent method, utilised by 42.5% of farmers, involves chopping the straw and incorporating it back into the paddy field, suggesting an emphasis on soil enrichment and sustainable practices. Selling straw bales is the next most common practice, employed by 32.5% of farmers, indicating a market-driven approach to straw management. Burning straw spread in the field is practised by 27.5% of farmers, reflecting traditional residue disposal methods. Using straw as feed for livestock (20.0%) and rolling with a heavy roller to crush straw into the soil (12.5%) are also significant. Other, less common methods include burning in a pile (10.0%), using it as vegetative mulch (10.0%), composting (7.5%), and utilising straw for mushroom production and making briquettes for bioenergy, each at 2.5%. These findings underscore the varied and resourceful strategies employed by farmers, driven by economic, agronomic, and environmental factors, and highlight opportunities for promoting more sustainable alternatives.

Figure 5.16 Options Respondents Use to Manage Rice Straw in the Dry Season



Source: Author's analysis, 2024.

In summary, both seasons share common methods for disposal of rice residues like chopping and incorporating straw, selling straw bales, and burning straw, but there are variations in their prevalence and additional practices. The wet season sees higher engagement in using vegetative mulch and slightly more burning practices, whereas the dry season shows an increased focus on selling straw bales and chopping and incorporating straw residue into the soil. The amount of rice straw present in the field ranges from about 450–800 kilgram/rai. Managing through the incorporation or baling of straw will incur additional labours and costs. Nevertheless, should farmers choose to sell the straw, their income could increase significantly, reaching around B1,000–B1,500 per rai. These differences reflect the adaptation of practices to seasonal conditions and available resources, demonstrating farmers' ability in sustainable rice straw management.

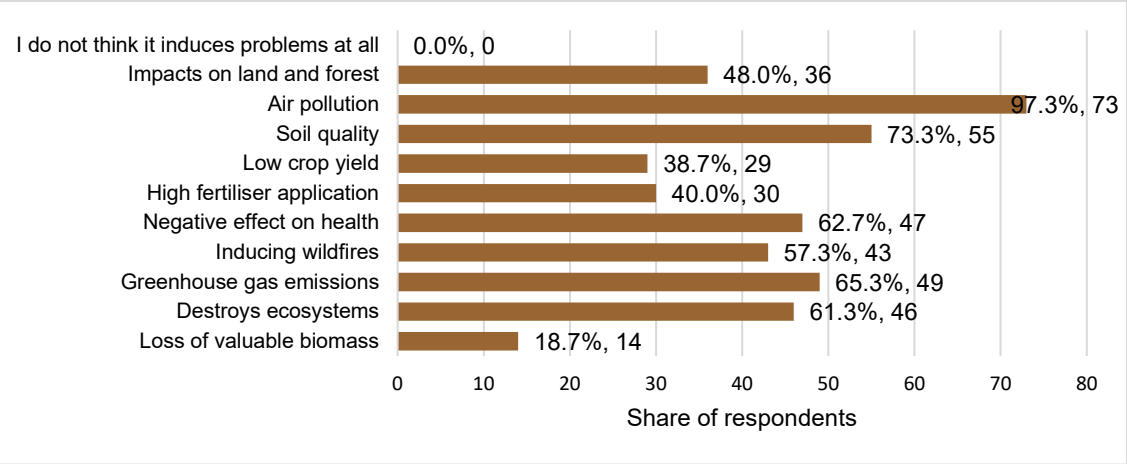
Farmers burn straw because it is a quick, easy, and low-cost option. Burning also saves time, creates a clean environment, and makes field preparation easier, particularly when straw is attached to a rotary tractor. It reduces costs because tractor service providers charge more if straw is not burned. It also aids in rice weed control, and is required when straw is wet or has a high moisture content and cannot be baled. Burning is commonly used in lowland rice areas with permanently submerged soil because tractors and baling machines cannot access the field.

In contrast, reasons for not burning rice straw include government and local prohibitions, using straw as a fertiliser by leaving it in the field or incorporating it into the soil, feeding livestock, and making extra money by selling straw bales, or using straw as vegetative mulch. Concerns about fire spread, air pollution, and smoke disturbing the community, as well as its negative effects on soil properties such as structure, microorganisms, and organic matter are additional reasons not to burn residue.

5.4.3 PART III: Respondents' Opinions on Problems Caused by Crop Burning

Most farmers (96%) know that burning rice straw has negative environmental impacts. Figure 5.17 shows farmers' opinions on the problems caused by crop burning. Crop burning is blamed for the vast majority (97.3%) of air pollution, making it the most widely recognised issue. Furthermore, 73.3% of farmers believe crop burning degrades soil quality, and 65.3% associate it with greenhouse gas emissions. Concerns about adverse health effects (62.7%) and ecosystem destruction (61.3%) are also prevalent. Many people have noted the effects on land and forests (48.0%), the occurrence of wildfires (57.3%), and the need for increased fertiliser application (40.0%). Only 18.7% believe crop burning causes the loss of valuable biomass. No farmers claimed that crop burning causes no problems at all. These findings highlight farmers' widespread understanding of the environmental and health risks associated with crop burning.

Figure 5.17 Respondents' Opinions on the Problems Created by Crop Burning

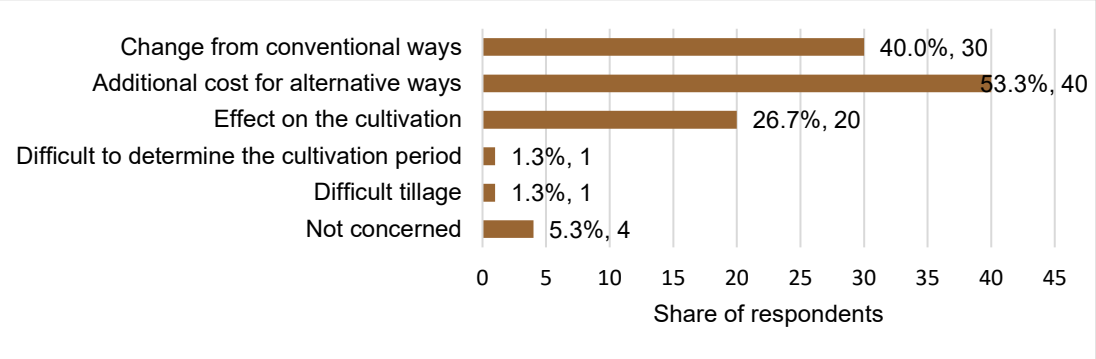


Source: Author's analysis, 2024.

Farmers have two main expectations from reducing crop burning. A significant majority, 82.7% of respondents, expect solutions that address the problems identified in crop burning, such as air pollution, soil degradation, and health issues as shown in Figure 5.17. Additionally, 49.3% of farmers are interested in solutions that enhance the cost-benefit balance of utilising crop residues. These insights indicate that farmers prioritise practical, effective solutions that mitigate the adverse impacts of crop burning while improving the economic viability of alternative residue management practices.

Figure 5.18 highlights several concerns farmers have regarding the reduction of crop burning. The primary concern, expressed by 53.3% of respondents, is the additional costs associated with alternative methods to burning. Another significant concern, noted by 40.0% of farmers, is the change from conventional ways of managing crop residue. Additionally, 26.7% of farmers are worried about the potential effects on cultivation practices. Less common concerns include difficulty in determining the cultivation period, difficult tillage, and no concern at all, each expressed by a minimal percentage of farmers (1.3% to 5.3%). These findings indicate that cost, adherence to traditional methods, and potential impacts on farming practices are the main challenges farmers face when considering the reduction of crop burning.

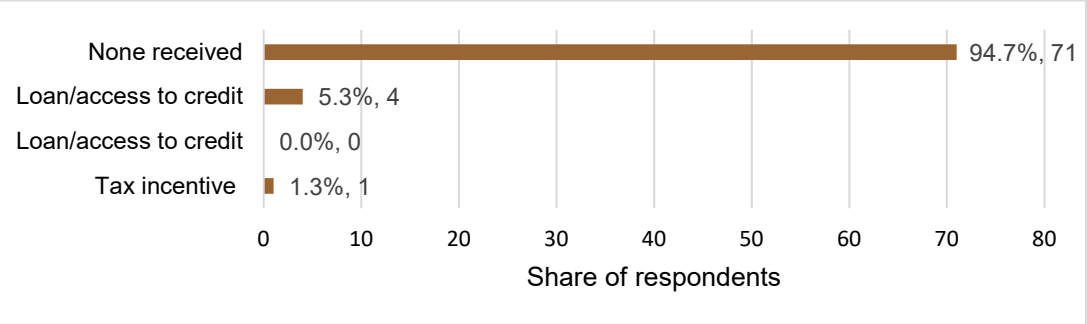
Figure 5.18 Respondents' Concerns About Reducing Crop Burning



Source: Author's analysis, 2024.

Figure 5.19 highlights a significant gap in financial support for farmers seeking to reduce crop burning. A substantial majority of respondents, 94.7%, indicated that there is no financial support available to promote this practice. Only a small fraction, 5.3%, mentioned loans as a form of support, and an even smaller percentage (1.3%) cited tax incentives. No respondents indicated access to credit or combined loan/credit options as available support. This lack of financial aid underscores the challenges farmers face in adopting alternative, more sustainable crop residue management methods, emphasising the need for increased financial assistance and policy interventions to support these efforts.

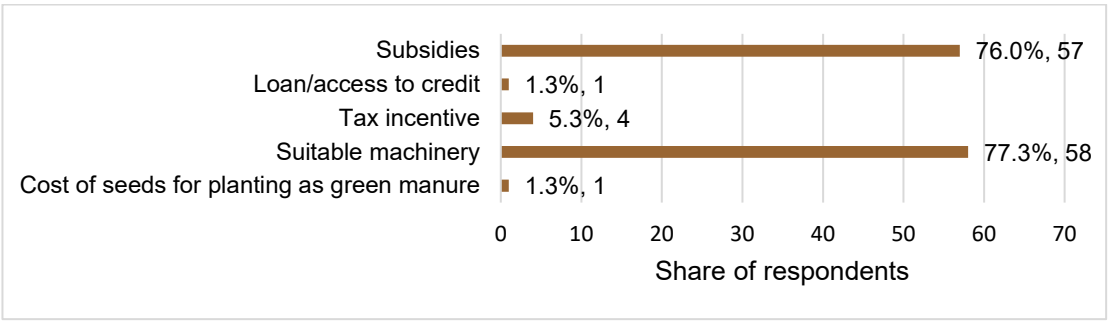
Figure 5.19 Financial Support Available to Respondents to Promote Reduced Crop Burning



Source: Author's analysis, 2024.

Figure 5.20 emphasises the types of financial support farmers need to reduce crop burning. The most sought-after support includes suitable machinery, requested by 77.3% of respondents, and subsidies, required by 76.0%. These are followed by tax incentives (5.3%), while only 1.3% of farmers indicated a need for loans/access to credit and the cost of seeds for planting as green manure. These findings underscore the importance of providing appropriate machinery and financial subsidies to support farmers in adopting more sustainable crop residue management practices.

Figure 5.20 Financial Support Needed by Respondents to Promote a Reduction in Crop Burning



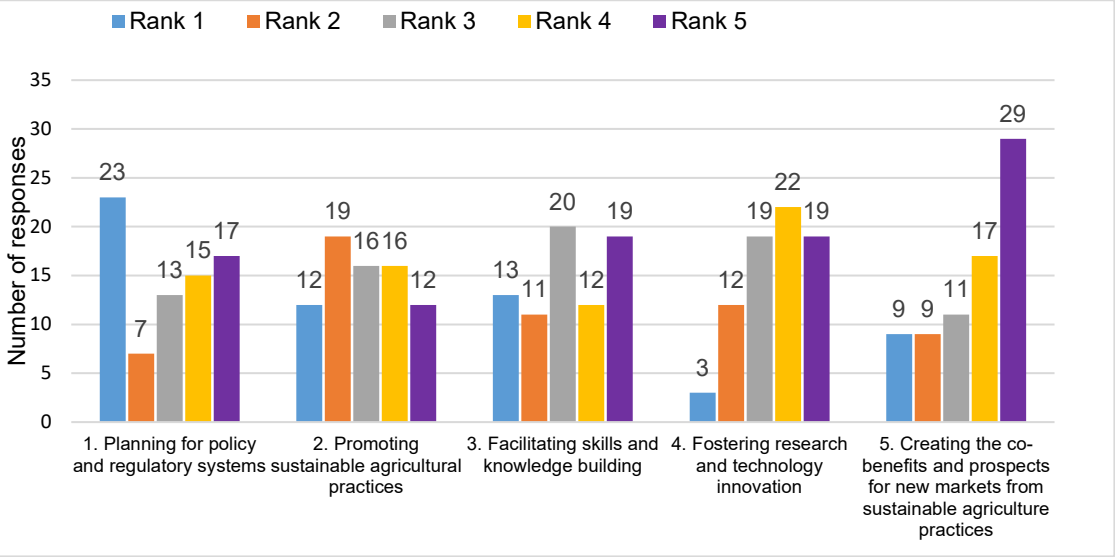
Source: Author's analysis, 2024.

5.4.4. PART IV: Respondents' Priorities for Activities to Reduce Crop Burning

Figure 5.21 summarises how 75 farmers ranked key activities to reduce crop burning across five priority levels. Planning for policy and regulatory systems emerged as the top priority, receiving the highest number of top priority responses (23 farmers). Promoting sustainable agricultural practices was consistently viewed

as important, with rankings spread across higher levels and most frequently placed second (19 farmers). Facilitating skills and knowledge building was mainly considered a mid-level priority, with the largest share of farmers assigning it third place (20 farmers). In contrast, fostering research and technology innovation was rarely ranked first (3 farmers) and was most commonly placed fourth (22 farmers), indicating it is seen as a supporting measure. Finally, creating co-benefits and new market prospects received the greatest number of fifth-place responses (29 farmers), suggesting it is generally viewed as a longer-term priority. Overall, the distribution reflects farmers' emphasis on immediate policy and practice-based actions, supported by capacity building, innovation, and future market development.

Figure 5.21 Respondents' Priorities to Reduce Crop Burning

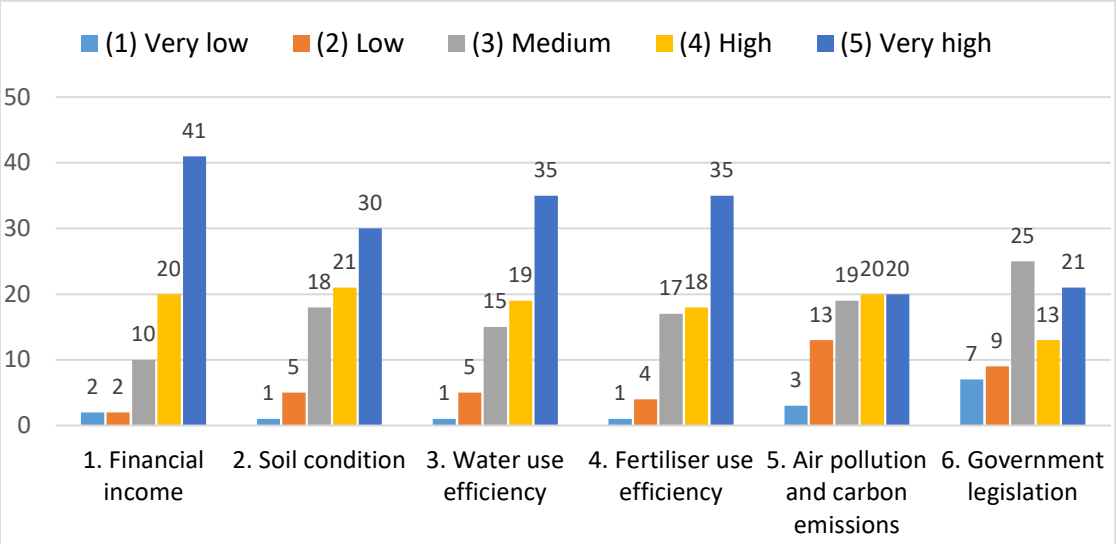


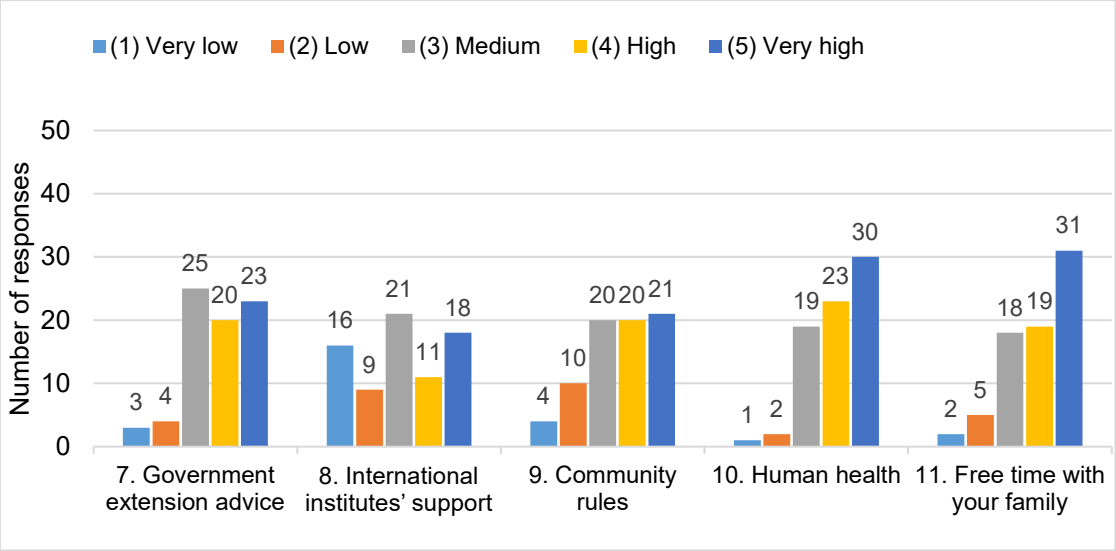
Source: Author's analysis, 2024.

Figure 5.22 presents farmers' ratings of the importance of different factors influencing agricultural decision-making, using a scale from (1) very low to (5) very high. Overall, farmers placed the strongest emphasis on economic and productivity-related considerations. Financial income was rated as very high by the largest group (41 farmers), while soil conditions also received a high level of importance, with 30 farmers assigning it a very high rating. Similarly, water-use efficiency and fertiliser use efficiency were widely prioritised, each receiving very high ratings from 35 farmers, reflecting farmers' focus on efficient resource management. Health and governance factors were also considered important. Human health was rated very high by 30 farmers, highlighting strong concern for well-being alongside production goals. Government legislation received a more moderate distribution, with the largest share of farmers rating it as medium (25

farmers) and very high (21 farmers). Community rules were similarly viewed as important, with 21 farmers selecting very high and 20 farmers selecting both medium and high. Environmental and support-related factors showed more mixed responses. Air pollution and carbon emissions were most often rated high or very high (20 farmers each), while government extension advice was commonly rated medium (25 farmers). International institutes' support received fewer top ratings, with the highest share at medium (21 farmers). Finally, free time with family received a broader spread, though it was still rated very high by 31 farmers, indicating that social well-being remains valued but varies in priority across respondents. Overall, the results highlight the wide range of economic, environmental, health, and social factors that farmers consider when making agricultural decisions.

Figure 5.22 Respondents' Rating of Most Important Factors for Agricultural Decision-Making



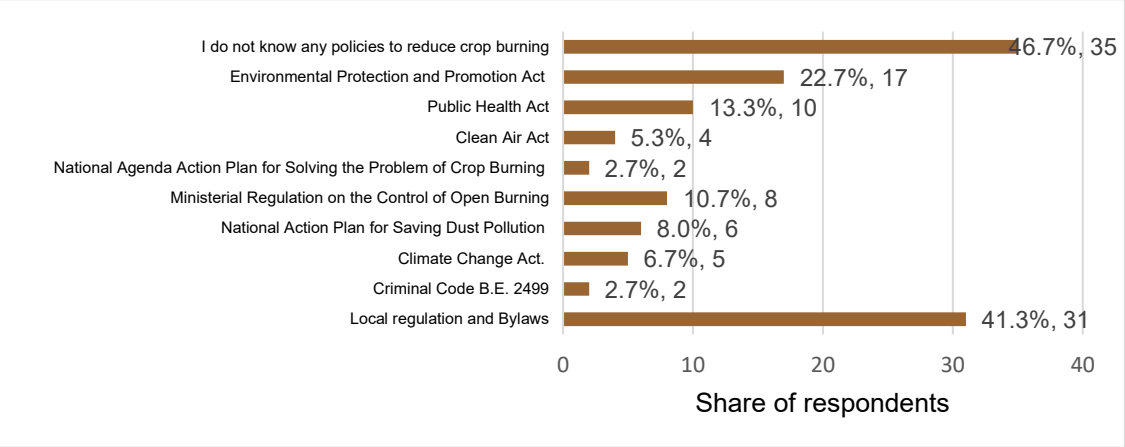


Source: Author's analysis, 2024.

5.4.5 PART V: Respondents' Awareness of Policies to Reduce Crop Burning

Figure 5.23 highlights that a significant number of farmers are unaware of policies aimed at reducing crop burning. Specifically, 46.7% of farmers (35 respondents) do not know any policies related to this issue. However, 41.3% (31 farmers) are aware of local regulations and bylaws. Other known policies include the Environmental Protection and Promotion Act (22.7%), the Public Health Act (13.3%), and the Ministerial Regulation on the Control of Open Burning (10.7%). Additionally, 8.0% of farmers are aware of the National Action Plan for Solving Dust Pollution, and smaller percentages know about the Climate Change Act (6.7%) and the Clean Air Act (5.3%). The least recognised policies include the National Agenda Action Plan for Solving the Problem of Crop Burning (2.7%) and the Criminal Code B.E. 2499 (2.7%). These findings underscore the need for increased awareness and dissemination of information regarding policies to effectively reduce crop burning amongst farmers.

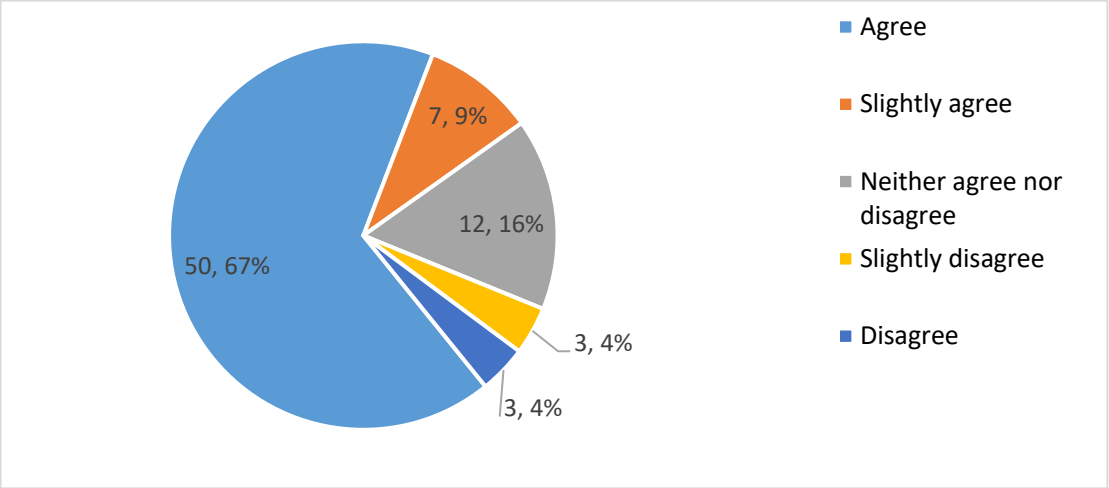
Figure 5.23 Respondents' Awareness of Policies to Reduce Crop Burning



Source: Author's analysis, 2024.

The pie chart in Figure 5.24 illustrates farmers' opinions about effectiveness of the promotion of crop-burning reduction policies. Many farmers (66.7%) agree that the policies have been well promoted. Meanwhile, 16.0% neither agree nor disagree, indicating some ambivalence. Additionally, 9.3% slightly agree, suggesting some positive acknowledgement, though not as strong. A small percentage of farmers slightly disagree or disagree, reflecting a minimal level of dissatisfaction. Overall, the data indicates a generally positive reception of the policy promotion efforts amongst farmers, with the majority acknowledging effective dissemination and implementation.

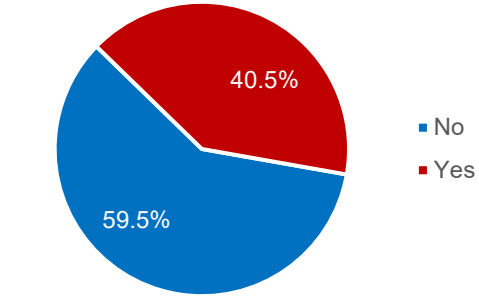
Figure 5.24 Respondents' Opinions on Whether Policies to Reduce Crop Burning Have Been Effectively Promoted



Source: Author's analysis, 2024.

Figure 5.25 indicates that most farmers (59.5%) are unaware of any non-formal or customary rules or local wisdom applied to reducing crop burning. However, 40.5% of farmers are aware of such measures. Amongst those who are aware, the responses highlight two key points: there is a ban on burning rice straw enforced by authorities, and agricultural assistance will be provided, with fines imposed on those who violate this rule. This data suggests that while a significant portion of farmers lack awareness of these rules, nearly half are informed about existing non-formal measures aimed at controlling crop burning, reflecting a mix of knowledge and enforcement challenges within the farming community.

Figure 5.25 Respondents' Awareness of the Application of Non-Formal Rules, Customary Rules, and Local Wisdom to Reduce Crop Burning



For Yes, I am aware

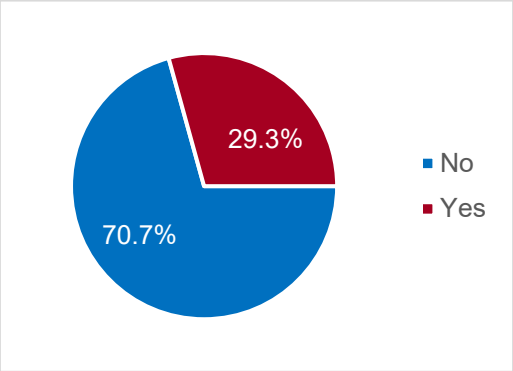
- There is a ban on burning rice straw, according to local authorities. Agricultural assistance will be suspended, and those who break this rule will be fined.
- If farmers burn straw, they will be fined B20,000.

B = Thai baht.
Source: Author's analysis, 2024.

5.4.6 PART VI: Respondents' Understanding of Capacity Building and Knowledge-Sharing for Reducing Crop Burning

Figure 5.26 shows that most farmers (70.7%) do not perceive capacity building and knowledge-sharing as effective in promoting crop-burning reduction. However, 29.3% of farmers believe that these efforts are beneficial. Amongst those who find it effective, key sources of capacity building and knowledge-sharing include the Facebook page, 'Weekend Farmer,' the District Agricultural Office, the internet (social media and websites), university/educational institutions, the no-burn project of the Agricultural Office, community learning centres, and the Sub-district Administrative Organisation. These findings suggest that while a significant portion of farmers remain sceptical, there is a notable group that values these educational and informational resources to help reduce crop-burning practices.

Figure 5.26 Respondents' Awareness of Sources of Capacity Building and Knowledge-Sharing to Promote a Reduction in Crop Burning



For Yes, I am aware

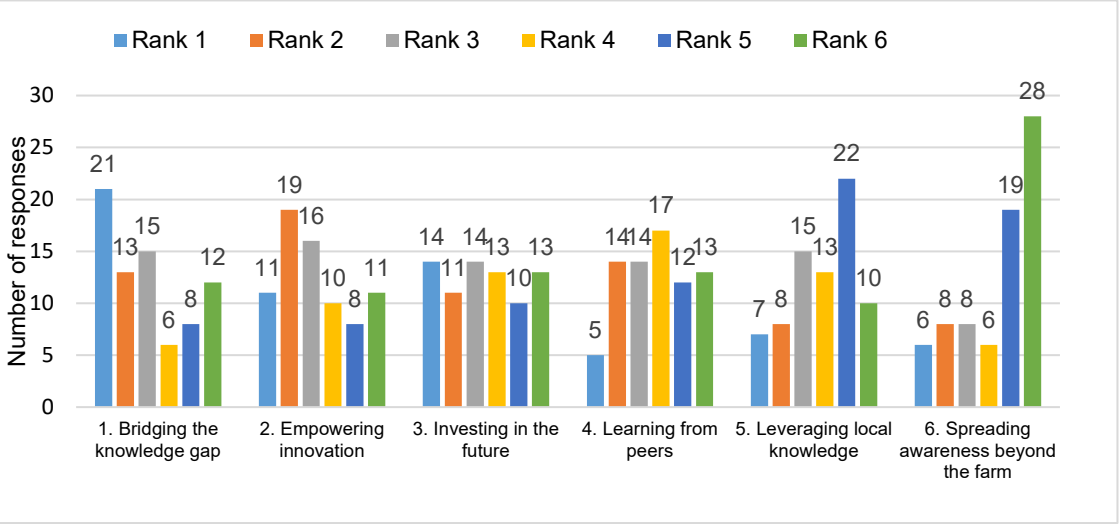
- Facebook page: 'Weekend Farmer'
- District Agricultural Office
- Internet (social media, websites)
- University/educational institutions
- No-burn project of the Agricultural Office
- Community learning centre
- Sub-district Administrative Organisation

Source: Author's analysis, 2024.

Figure 5.27 highlights how farmers prioritised different opportunities to support the reduction of agricultural burning. Bridging the knowledge gap emerged as the top priority, receiving the highest number of first preference responses (21 farmers). In contrast, spreading awareness beyond the farm was most frequently placed as the lowest priority, with the largest share of the bottom rankings (28 farmers), suggesting that broader outreach is viewed as a longer-term need compared with immediate on-farm support.

Other opportunities including empowering innovation, investing in the future, and learning from peers showed more balanced distributions across rankings. For example, empowering innovation was most often placed second (19 farmers), while learning from peers received its was in fourth place (17 farmers). Leveraging local knowledge was frequently assigned the fifth position (22 farmers), reflecting mixed perceptions of its urgency. Overall, the findings highlight farmers' strong emphasis on addressing knowledge gaps, alongside the supporting roles of innovation, peer learning, and longer-term awareness-building initiatives.

Figure 5.27 Respondents' Priorities for Methods to Promote a Reduction in Agricultural Burning

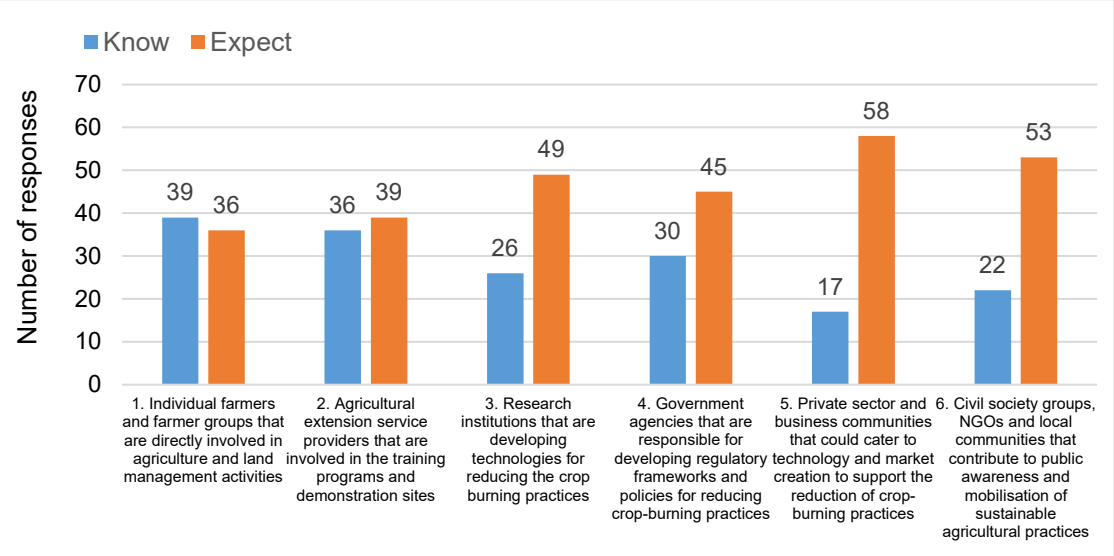


Source: Author's analysis, 2024.

5.4.7 PART VII: Respondents' Knowledge of and Expectations around Collaborative Activities to Reduce Crop Burning

Figure 5.28 highlights a gap between farmers' knowledge and expectations regarding collaborative activities to reduce crop burning. The top the categories where farmers' expectations significantly outstrip their knowledge are research institutions, government agencies, and private sector/business communities. Farmers expect more involvement from research institutions (49 vs. 26 of those who know), government agencies (45 vs. 30 of those who know), and private sector/business communities (58 vs. 17 of those who know). There is also a notable expectation for agricultural extension service providers, with 39 farmers expecting involvement versus approximately 35 who know. Individual farmer or farmer group involvement matches their expectations and knowledge (35 for both). Civil society groups, non-governmental organisations, and local communities also have higher expectations (53) compared to knowledge (22). This data underscores the need for enhanced collaboration, communication, and support from various stakeholders to meet farmers' expectations and effectively reduce crop-burning practices.

Figure 5.28 Collaborative Activities that Respondents Know and Expect



NGO = non-governmental organisation.
Source: Author's analysis, 2024.

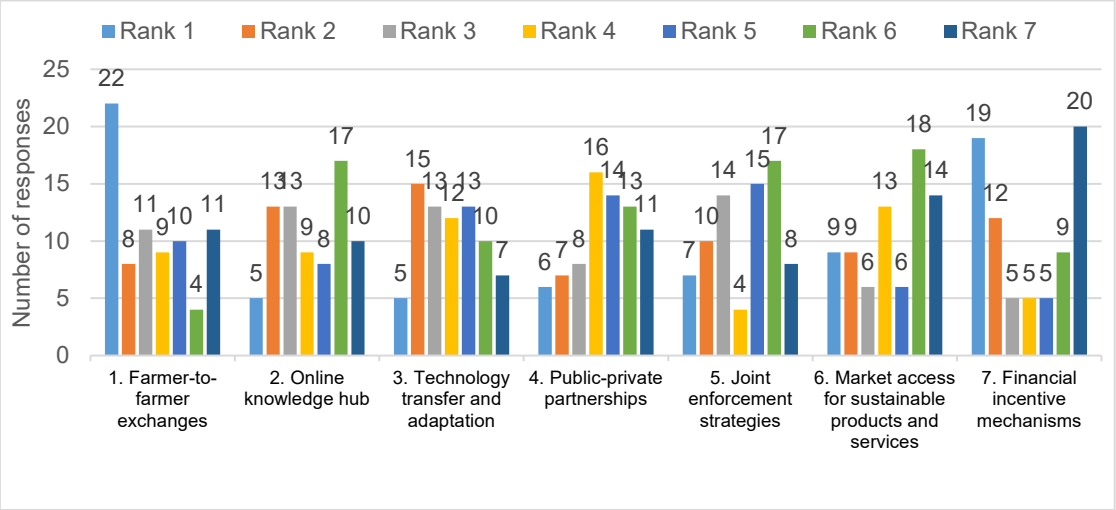
Figure 5.29 indicates that farmers have clear preferences for programmes to scale up their involvement in reducing crop burning. Farmer-to-farmer exchanges emerge as the top priority, receiving the highest number of first preference responses (22 farmers), highlighting the importance of peer learning and shared experience. The online knowledge hub was most frequently placed at a lower priority level, with the largest share of farmers assigning to sixth position (17 farmers), suggesting that while digital resources are valued, they may be considered less immediate than direct interaction.

Technology transfer and adaptation attracted notable support as an upper-level priority, with 15 farmers placing it second, while public–private partnerships were most commonly ranked fourth (16 farmers), indicating their role as mid-level priorities. Joint enforcement strategies received moderate interest, with the highest concentration also appearing in the sixth category (17 farmers), implying that enforcement is viewed as a supporting or longer-term measure.

For market- and finance-related programmes, market access for sustainable products and services was most frequently ranked sixth place (18 farmers), suggesting relatively low urgency among respondents. Meanwhile, financial incentive mechanisms showed the widest variation, with a substantial number of farmers placing it as the lowest priority in seventh position (20 farmers), indicating differing perspectives on the role of financial support.

Overall, the results emphasise farmers' strongest preference for peer-based learning approaches, alongside varying levels of interest in technological, institutional, market, and incentive-based programmes.

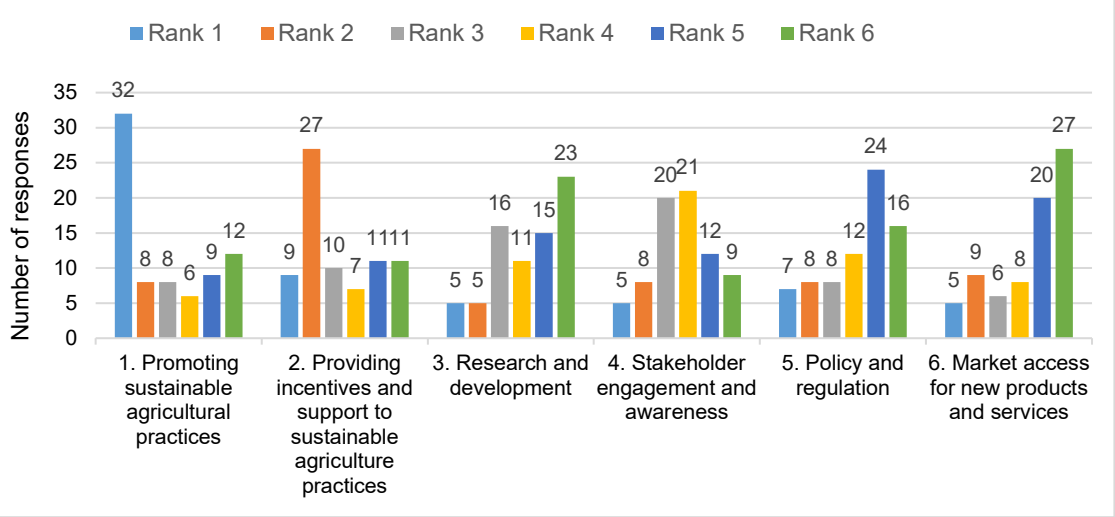
Figure 5.29 Programmes That Respondents Would Like to Prioritise to Scale up Involvement in Reducing Crop Burning



Source: Author's analysis, 2024.

Figure 5.30 prioritises six integrated strategies to promote crop-burning reduction. Promoting sustainable agricultural practices emerged as the strongest top priority, receiving the highest number of first place responses (32 farmers), indicating that farmers view practical on-farm improvements as the most immediate and important strategy. Providing incentives and support to sustainable agriculture practices was most frequently ranked as the second priority, with 27 farmers assigning it Rank 2, highlighting the importance of financial and institutional support in encouraging adoption. Research and development was most commonly placed as the lowest priority, receiving the largest share of sixth--place rankings (23 farmers), suggesting that farmers may see research as a longer-term supporting measure rather than an urgent need. Stakeholder engagement and awareness was most often ranked fourth (21 farmers), reflecting the recognised value of broader participation and education. Meanwhile, policy and regulation received its highest concentration in fifth place (24 farmers), indicating that governance is considered important but secondary to direct practice-based interventions. Finally, market access for new products and services was most frequently assigned the lowest priority, with 27 farmers placing it at Rank 6, showing that market development is viewed as a longer-term component of the overall strategy. Overall, the findings emphasise farmers' preference for immediate action through sustainable practices and incentives, supported by engagement efforts, regulatory frameworks, and longer-term research and market opportunities.

Figure 5.30 Respondents' Views on Integrated Strategies Needed to Promote a Reduction in Crop Burning

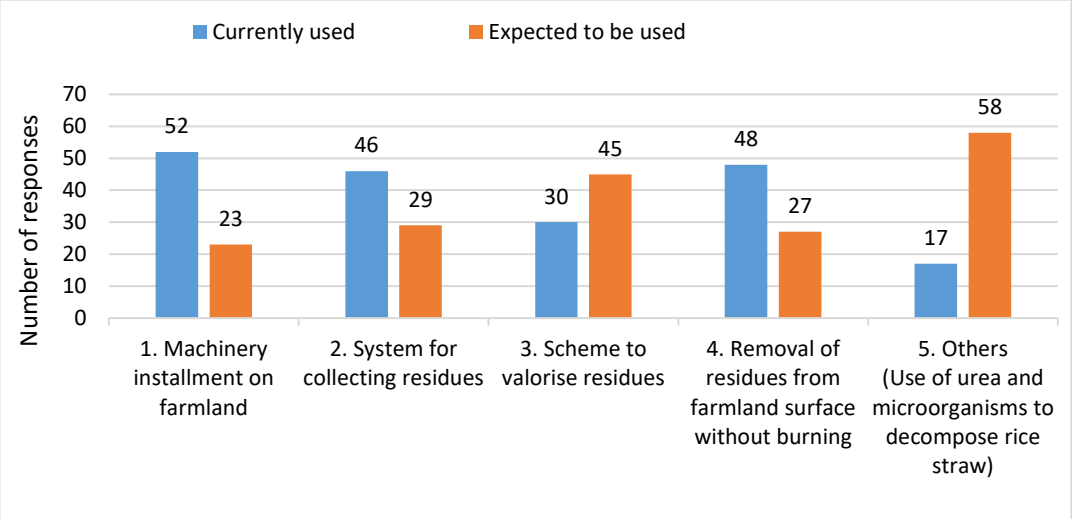


Source: Author's analysis, 2024.

5.4.8 PART VIII: Respondents' Attitudes to Current and Future Technology Use to Reduce Crop Burning and Utilise Residue

Figure 5.31 highlights the gap between technologies that farmers report as currently used and those they expect to be adopted in the future to reduce crop burning and improve crop residue utilisation. At present, the most commonly implemented options are machinery installation on farmland (52 farmers) and systems for collecting residues (46 farmers). However, fewer farmers expect these approaches to expand further, with only 23 farmers and 29 farmers, respectively, identifying them as future priorities. In contrast, several technologies show stronger future expectations than current use. A scheme to valorise residues is currently recognised by 30 farmers, but expected by a larger group (45 farmers). The strongest increase is seen in other methods, such as using urea and microorganisms to decompose rice straw, which is currently used by only 17 farmers but expected by 58 farmers, making it the most anticipated future approach. Similarly, removal of residues from farmland without burning is currently practised by 48 farmers, yet only 27 farmers expect it to be further implemented. These findings reveal a considerable gap between the current implementation and farmers' expectations, emphasising the need for increased awareness and adoption of newer and more effective technologies for sustainable residue management.

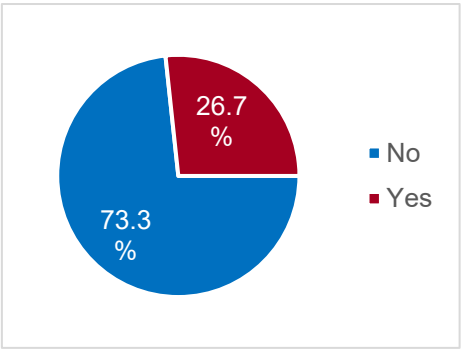
Figure 5.31 Respondents' Perceptions of Technologies Already Implemented and Those Expected to be Implemented to Reduce Crop Burning and Utilise Crop Residues



Source: Author's analysis, 2024.

Figure 5.32 indicates that 26.7% of farmers perceive that new technology has been implemented in recent practices, while 73.3% do not share this view. Amongst those who recognise new technological implementation, the practices mentioned include using decomposing microorganisms from the Land Development Department, using urea to decompose rice straw, employing straw choppers and straw spreaders, engaging in ratoon rice cultivation, baling straw, and incorporating remaining stubble into the soil. These practices highlight the specific methods being adopted by a minority of farmers who acknowledge technological advancements in their agricultural practices.

Figure 5.32 Respondents' Awareness of Recent Practices Following Implementation of New Technology



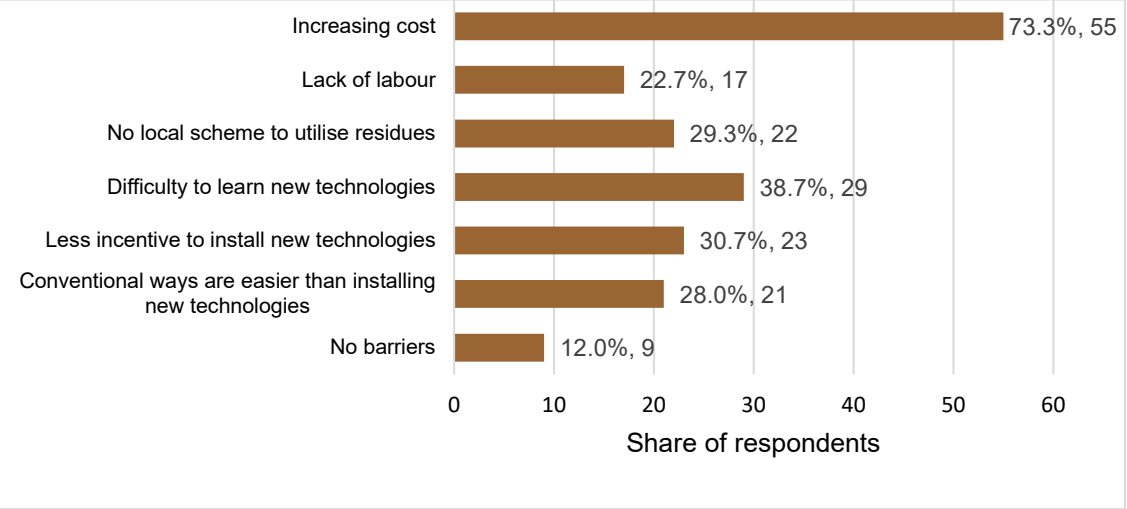
For Yes, I am aware.

- Using decomposing microorganisms from the Land Development Department
- Using urea to decompose rice straw
- Straw choppers and straw spreaders
- Ratoon rice cultivation
- Straw baling
- Incorporating remaining stubble into

Source: Author's analysis, 2024.

Figure 5.33 highlights the barriers farmers face in adopting new technologies to reduce crop burning. The most significant barrier is the increasing cost, with 73.3% of respondents identifying it as a major challenge. Additionally, 38.7% of farmers find it difficult to learn new technologies, and 30.7% cite a lack of incentives to install them. The absence of local schemes to utilise residues is another notable barrier, mentioned by 29.3% of farmers. Furthermore, 28.0% of respondents believe conventional methods are easier than adopting new technologies. The lack of labour is a concern for 22.7% of farmers, while only 12.0% report no barriers at all. These findings emphasise the need for cost-effective, easy-to-learn technologies, better incentives, and local support schemes to promote sustainable crop residue management practices.

Figure 5.33 Respondents' Views on Barriers to Installing New Technologies to Reduce Crop Burning

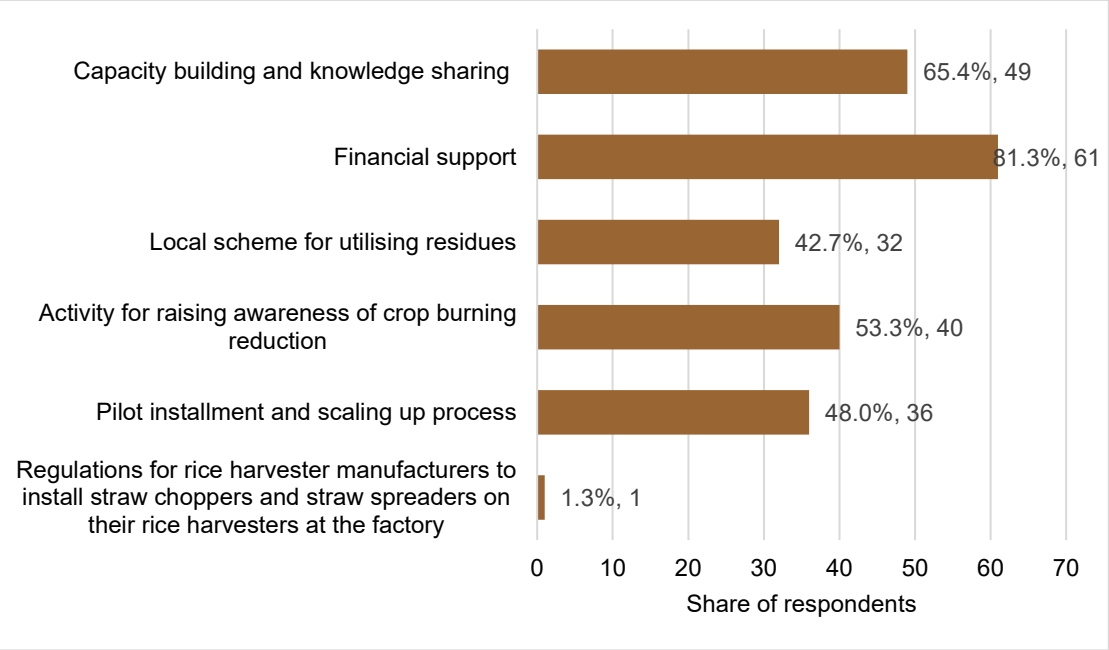


Source: Author's analysis, 2024.

For respondents who chose options other than 'No barriers' to installing new technologies for crop-burning reduction, Figure 5.34 highlights several possible solutions to promote the implementation of new technologies to reduce crop burning and utilise crop residues. The most favoured solution, endorsed by 81.3% of respondents, is financial support, reflecting the critical need for funding to facilitate technology adoption. Capacity building and knowledge-sharing are also highly valued, with 54.7% of farmers advocating for these efforts to enhance understanding and skills. Raising awareness of crop-burning reduction is another significant solution, supported by 53.3% of respondents. Local schemes for utilising residues receive backing from 42.7% of farmers, indicating the importance of community-based initiatives. Additionally, 37.3% of respondents support pilot

instalment and scaling-up processes to test and expand successful technologies. Notably, a small percentage of farmers (1.3%) believe regulations for rice harvester manufacturers to install straw choppers and spreaders at the factory would be beneficial. These findings highlight the diverse strategies farmers consider essential, emphasising the need for comprehensive financial, educational, regulatory, and community-driven approaches to effectively promote new technologies.

Figure 5.34 Respondents' Views on Solutions to Promote the Implementation of New Technologies



Source: Author's analysis, 2024.

5.5 Summary and Recommendations

5.5.1 Summary

The study reveals diverse patterns in farmer organisation, financing, and crop management practices. Notably, membership of farmer associations varies considerably, with Mega Farming Group (42.7%) and Small & Micro Community Enterprise (41.3%) leading, yet nearly 30.0% of farmers remain unaffiliated. In terms of financing, the Bank for Agriculture and Agricultural Cooperatives dominates as the preferred credit source (60.0%), with a significant reliance also on Village Funds (40.0%) and agricultural co-operatives, though 16.0% of farmers do not use any credit sources.

Regional differences in rice cultivation are evident. In the wet season, Lower

Northern farmers favour non-photoperiod-sensitive varieties (e.g. RD13, RD41, RD85), while Northeastern farmers prefer photoperiod-sensitive types, such as the sticky rice variety RD6 and Khao Dawk Mali 105. Dry season cultivation is mostly confined to irrigated areas in the Lower Northern region.

Extension support is uneven. While initiatives in sustainable rice farming, Maga-Farm, and climate-smart agriculture reach a notable portion of farmers, over one-third report receiving no support. Similarly, support for rice straw management technologies is minimal, with 84.0% of farmers not receiving any assistance.

Crop residue management practices vary by season. Common methods include chopping and incorporating straw into the paddy, using it as livestock feed, burning, and selling straw bales. Despite widespread recognition (96.0%) of the negative environmental and health impacts of burning air pollution (97.3%), soil degradation (73.3%), and greenhouse gas emissions (65.3%) burning remains prevalent due to its low cost, ease, and role in weed control.

For additional suggestions, manufacturers of rice harvesters should have rules allowing them to equip their machines from the factory with straw spreaders and choppers. The shorter pieces of the chopped rice straw will make field management following harvest easier. In general, if there is still water in the fields in the Lower Northern and central areas of Thailand during the harvest, rice harvesters are not suitable for baling and cannot move the straw out of the fields. Moreover, they are not worth the management expense since they are costly and moving them requires labour. Cutting fresh straw and distributing it following harvest, then mixing it with the soil with a rotating hoe and controlling the water without soaking it, helps the straw break down rapidly, so lowering the fertiliser costs and the labour requirements.

Farmers express strong expectations for solutions that address environmental issues and improve the economic viability of alternative residue management. However, cost, adherence to traditional practices, and the absence of financial support (94.7% report no available support) are key barriers. Additionally, there is a clear gap between the technologies currently implemented and what farmers expect, with cost and ease of learning new practices emerging as major hurdles. Finally, farmers indicate a need for enhanced collaboration and outreach, with a strong preference for farmer-to-farmer exchanges, online knowledge hubs, and comprehensive integrated strategies.

5.5.2 Recommendations

- Enhance financial assistance. Enhancing financial assistance is necessary to further reduce crop burning. For instance, increasing subsidies and

providing suitable machinery enables farmer to adopt alternative, sustainable rice straw management practices. Furthermore, targeted credit schemes that include incentives for sustainable practices, reducing the reliance on conventional burning methods, should be developed.

- Strengthen extension and capacity building. To promote activities to reduce crop burning, improved outreach should expand the extension services to ensure that a greater number of farmers receive support, particularly in areas of sustainable farming and new technology adoption. Educational programmes are also necessary to promote farmer-to-farmer exchange programmes, online knowledge hubs, and capacity building workshops to disseminate best practices and innovative residue management techniques.
- Promote alternative residue management practices. Alternative residue management practices should be shared more through demonstration projects, which establish pilot projects and demonstration sites to showcase effective alternatives to burning, such as straw incorporation, baling, composting, and using straw as livestock feed. Developing local schemes for residue utilisation that can reduce additional costs, thereby making alternative methods more economically attractive is require as well to promote alternative residue management.
- Increase policy awareness and regulatory support. From a policy perspective, enhancing communication efforts to improve farmers' awareness of existing formal and informal policies on crop burning reduction is required. Additionally, strengthening the enforcement of regulations that discourage burning would also be effective, alongside providing incentives for adopting environmentally friendly practices.
- Foster multi-stakeholder collaboration. Partnerships amongst government agencies, research institutions, private sector entities, and community organisations should be encouraged to support integrated strategies that address both environmental and economic challenges. The strategies would also be developed with joint programmes that balance policy, technological innovation, and market access to create a comprehensive framework for reducing crop burning.

These recommendations aim to reduce crop-burning practices and foster a more sustainable and resilient agricultural systems by addressing financial constraints, enhancing technical support, promoting sustainable alternatives, and improving policy outreach and collaboration.

References

Chang, C.H., C.C. Liu, and P.Y. Tseng (2013), 'Emissions Inventory for Rice Straw Open Burning in Taiwan Based on Burned Area Classification and Mapping Using Formosat-2 Satellite Imagery', *Aerosol and Air Quality Research*, 13, pp.474–87. https://doi.org/10.4209/aaqr.2012.06.0150

Engling G, J. Lee, Y. Tsai (2009), 'Size-Resolved Anhydrosugar Composition in Smoke Aerosol from Controlled Field Burning of Rice Straw', *Aerosol Science and Technology,* 43(7), pp.662–72. https://doi.org/10.1080/02786820902825113

Gummert, M. (2024), *Piloting Sustainable Use of Rice Straw – A Feasibility Study.* Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). https://asean-agrifood.org/piloting-sustainable-use-cases-of-rice-straw-a-feasibility-study/

International Rice Research Institute (IRRI) (2019), *Rice Straw*. [Online] accessed 29 Oct 2023 from http://www.knowledgebank.irri.org/step-by-step-production/postharvest/rice-by-products/rice-straw.

Jenkins, B.M. et al. (2003), Rice Straw Smoke Generation System for Controlled Human Inhalation Exposures. Aerosol Science Technology, 37(5), pp.437–54. https://doi.org/10.1080/02786820300977

Kim Oanh, N.T. et al. (2011), 'Characterization of Particulate Matter Emission from Open Burning of Rice Straw', *Atmospheric Environment* 45(2), pp.493–502. https://doi.org/10.1016/j.atmosenv.2010.09.023

Mandal, K.G., A.K. Misra, K.M. Hati, K.K. Bandyopadhyay, P.K. Ghosh, and M. Mohanty (2004), 'Rice Residue Management Options and Effects on Soil Properties and Crop Productivity', *Food Agriculture and Environment*, 2, pp.224–31. https://scispace.com/papers/rice-residue-management-options-and-effects-on-soil-1hjuruvedd.

Office of Agricultural Economics (OAE). (2023), *Agricultural Statistics of Thailand 2023*. Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. https://www.oae.go.th/assets/portals/1/files/jounal/2567/statistic2566.pdf

Ponnamperuma, F.N. (1984), 'Straw as a Source of Nutrients for Wetland Rice', *Organic Matter and Rice*. Los Baños: IRRI. pp.117–35.

Rice Department (2016), *Rice Knowledge Bank (version 3.0),* Bangkok: Rice Department. https://rkb.ricethailand.go.th/web/index.php.

Chapter 6

Case Study on Reducing Crop Burning in ASEAN Member States: Sugarcane Trash Management in Viet Nam

Nguyen Min Hieu

6.1 Introduction

The Southeast Asia region produces a variety of crops, including rice, sugarcane, maize, cassava, and horticultural products. These crops generate substantial residues annually, most of which are burned in the field. Open burning releases significant pollutants, contributing to environmental degradation and energy waste. Additionally, this practice reduces soil organic matter, necessitating higher applications of fertilisers, particularly nitrogen (Open burning sugarcane trash reduced the organic carbon by 0.02%, available N by 15 kg ha–1 and available P by 16 kg ha–1 (Yadav et al., 1994).

Rice straw burning dominates emissions (85%–98%) in Southeast Asia, followed by sugarcane, maize, and soybean residues (Kim Oanh et al., 2018). Sugarcane cultivation generates approximately 8–10 tonnes of trash per hectare (Chandel et al.,2012), including leaves, tops, and water shoots. Due to limited utilisation options, farmers often practice open burning to prepare fields for subsequent crops.

While burning sugarcane trash has certain perceived advantages, such as eliminating weeds and pests, it also causes detrimental effects, including a 32.0% reduction in bud germination due to heat exposure (Suma and Savitha, 2015). Furthermore, this practice diminishes soil nutrients, reducing sugarcane yield by 13.2% in ratoon crops (Yadav et al., 1994).

In contrast, the utilisation of sugarcane trash offers numerous benefits. Composting sugarcane trash can improve soil fertility and reduce fertiliser use by 10.4% per hectare (Nakhla, Mahmoud, and Haggar, 2017). Applying green trash mulch enhances soil organic carbon, nitrogen, and water retention while co-firing sugarcane trash with bagasse provides an alternative fuel source for cogeneration plants (Seebaluck and Seeruttum, 2009).

In Viet Nam, green sugarcane is typically harvested without pre-harvest burning. Mechanised harvesting, which is suitable for large plantations and allows sugarcane trash to be shredded and used as mulch. However, small-scale farmers

often burn trash for convenience. While some have begun using vegetative mulching, the practice of burning remains prevalent, highlighting a need for sustainable management solutions.

6.2 Study Methodology

This study investigated sugarcane trash management practices in Viet Nam through a comprehensive survey across three dominant sugarcane regions: North Coastal, South Coastal, and Central Highland. The survey recruited 97 participant farmers who provided detailed information about their manpower, farm sizes, and current trash management practices. The survey employed Statistical Package for Social Sciences software for data analysis, allowing for opinion measurement of farmers' attitudes, perceptions, and preferences.

The study explored farmers' perceptions of the environmental and agricultural impacts of burning, barriers to adopting sustainable practices, and potential solutions. The rating scale enabled quantification of the intensity of farmers' opinions, ranging from strong agreement to strong disagreement on various aspects of sugarcane trash management. The data collection emphasised understanding regional differences in methods such as open burning, vegetative mulching, and shredding. Farmers also shared insights on challenges, including costs, labour availability, and technical knowledge gaps, with the rating scale helping to rank the relative importance of these factors to provide actionable recommendations. The study incorporated responses regarding financial support, policy awareness, and stakeholder collaboration. In addition, the Likert scale was used for a more precise assessment of farmers' priorities and needs, facilitating the development of targeted interventions and policies.

This methodology provided a strong framework for analysing complex attitudes and behaviours related to sugarcane trash management, offering valuable insights for policymakers and agricultural stakeholders.

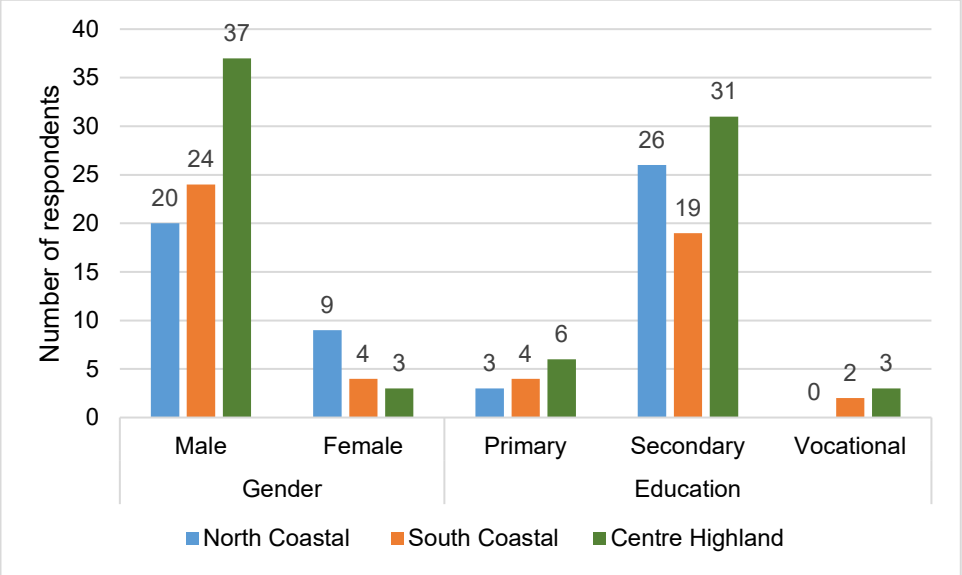
6.3 Study Results

6.3.1 Respondent Identity

Those interviewed were 97 individual farmers. The majority of respondents (83.5%) were male. The number of female farmers who directly cultivate sugarcane differs significantly across regions with higher participation in the North Coastal region, which is characterised by small-plot plantations. Farmers who completed secondary education account for 78.5%, of respondents, which is favourable for the adoption of new techniques for sustainable agriculture, whereas vocation-trained

farmers are rare. Family sizes range from three to six members, but the nuclear family is dominant (Figure 6.1).

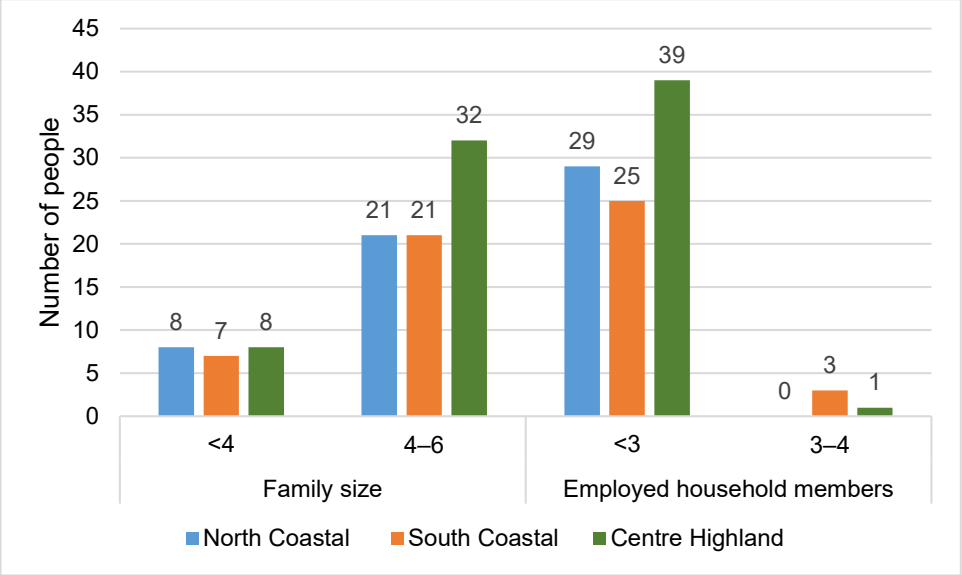
Figure 6.1. Gender and Education of Respondents



Source: Author's analysis, 2024.

Figure 6.2 shows that household sizes with four to six members are most common in three regions, with 76.3%. In contrast, smaller households, with fewer than four members, are less common and normally consist of elderly couples. The manpower directly involved in farming is low, with most households (95.9%) having fewer than three people engaged in farm work. Therefore, during harvesting and planting periods, households have to employ workers who are specialised in those practices.

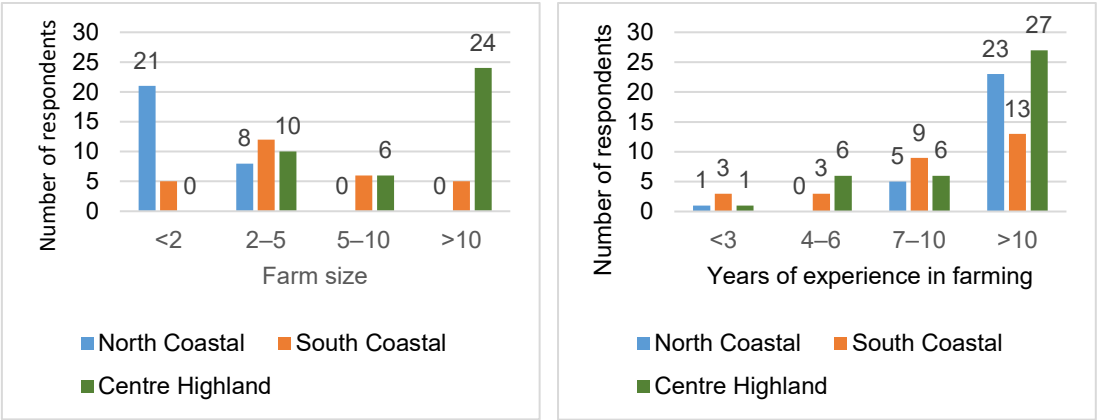
Figure 6.2. Family Size and Number of Employed Household Members



Source: Author's analysis, 2024.

Sugarcane farm sizes vary across regions. Farms ranging from 2 to 5 hectares are popular in three regions and are owned by 30.9% of the respondents. However, small farms are more common in the North and South Coastal regions, accounting for 26.8% of the respondents. Large farms are popular in the Central Highland region, which has abundant, hilly land and accounts for 29.9% of the respondents.

Figure 6.3. Farm Size and Respondents' Years of Experience in Farming



Source: Author's analysis, 2024.

Most farmers have more than 10 years of experience and account for 64.9% of the respondents, followed by 20.6% of respondents with at least 7 years of experience (Figure 6.3). Most sugarcane farmers are over 40 years old and live in rural areas, which contributes to limited awareness of air pollution caused by agricultural crop

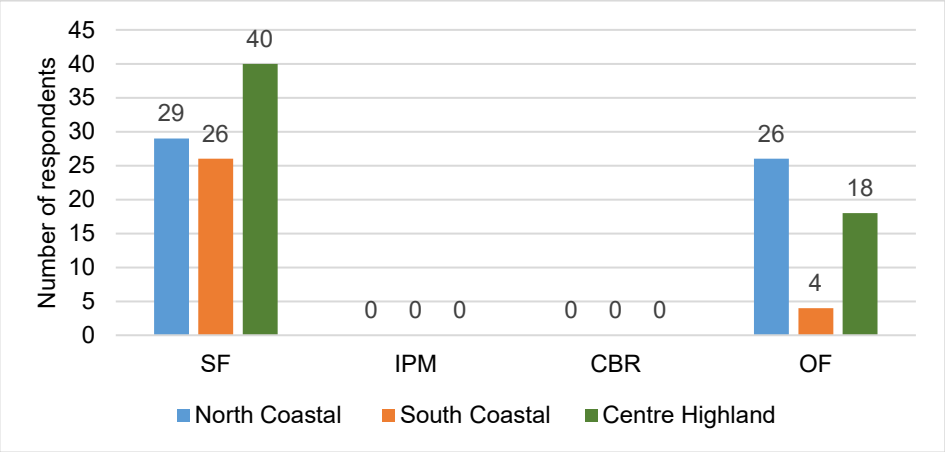
burning.

6.3.2 Current Status of Sugarcane Cultivation in Viet Nam

There are three groups of cane variety: non-detrash, semi-detrash, and self-detrash. The semi-detrash group has thin leaf sheaths which can be detrashed manually. Once the dried leaf sheaths are detrashed and decomposed, they can help conserve soil moisture, regulate soil temperature, and provide some nutrients. For this reason, semi-detrash group variety is the primary cultivation and is grown in all three regions by 75.9% of the respondents. This is followed by non-detrash (14.6% of respondents) and self-detrash (9.5% of respondents).

Sugar mills often conduct training courses to disseminate advanced techniques for farmers. The survey shows that numerous farmers have joined sustainable sugarcane farming courses (97.9%), and half of them are trained in organic fertiliser application, but the training is completely focused on filter cake and ash from sugar mills (Figure 6.4). At the time of writing, there are no training courses and extension services that aim at reducing cane trash burning.

Figure 6.4. Extension Services and Support Received by Respondents



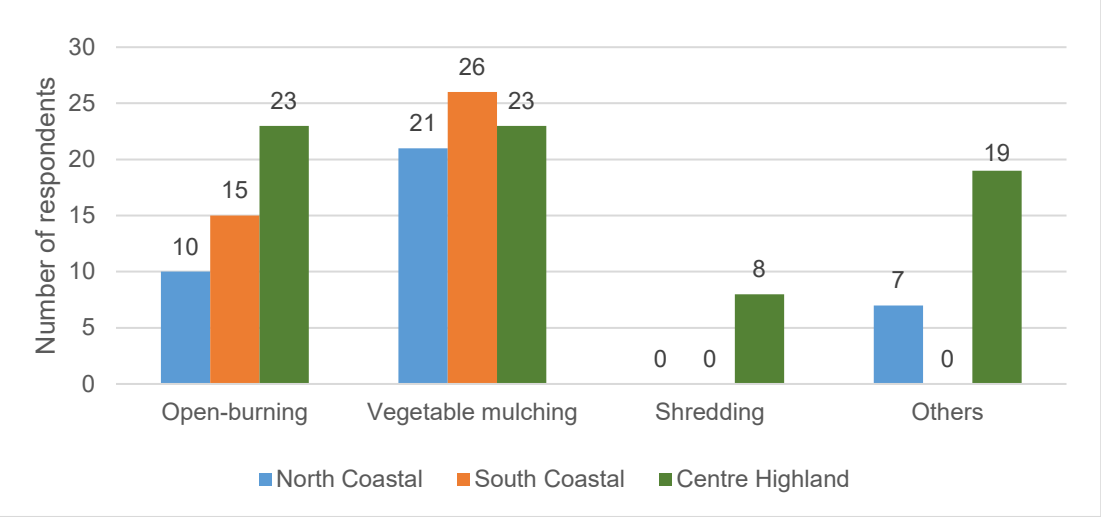
CBR = crop-burning reduction technologies; IPM = Integrated pest management; OF = organic fertiliser; SF = sustainable sugarcane farming.
Source: Author's analysis, 2024.

Cane trash management is mainly carried out by open burning and vegetative mulching. Shredding is still at the primary stage of adoption and is applied only in a small area. For the last crop cycle, all cane trash is openly burned in the field, to facilitate land preparation and new planting in the next cycle, as well as to reduce

pest disease and borers. The burning cost is about $3–$4[5] for each hectare, depending on the plot size; small plots are costlier than large ones.

For normal crops, cane trash management methods differed significantly across regions. Open burning was reported by 31.6% of respondents, primarily for convenience in field preparation. Vegetative mulching, adopted by 46.0% of the respondents, was the most common alternative, particularly in the Central Highland. Shredding was done by only 5.3% of the respondents, which was the least implemented practice and was only carried out in the Central Highland. Other approaches, such as using green tops and water shoots as cattle feed, accounted for 17.1% of the respondents, which is mainly in locations that have small cow farms. The adoption of vegetative mulching practices by farmers has expanded significantly due to their benefits compared with 5 years ago. Around 45 farmers kept cane trash in the field as vegetative mulching, and 25 farmers practised both vegetative mulching and open burning (Figure 6.5).

Figure 6.5. Respondents' Methods of Cane Trash Management

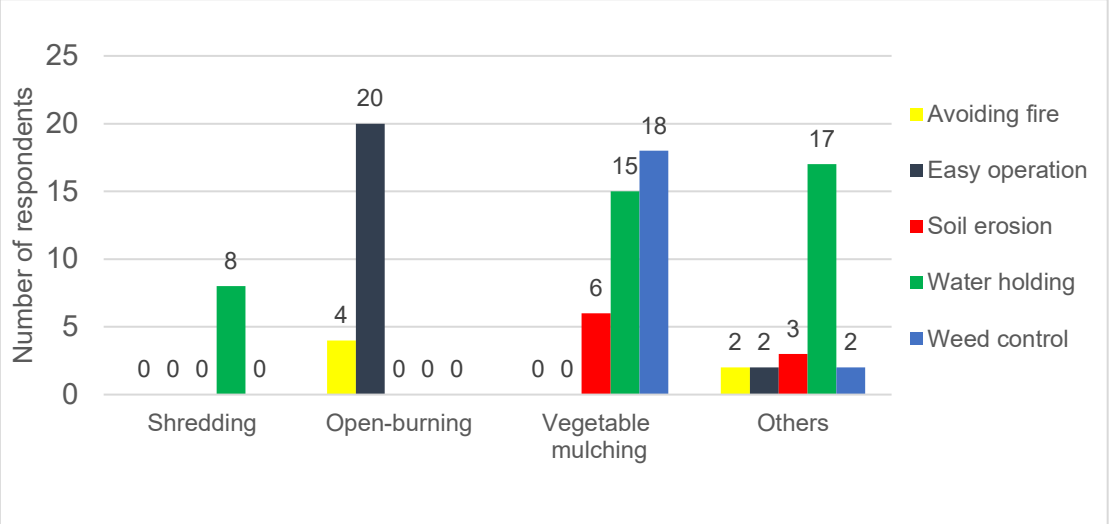


Source: Author's analysis, 2024.

Respondents who practised vegetative mulching cited benefits such as reduced soil erosion (9.3%), decreased weed growth (20.6%), and better soil water retention (41.2%). However, the high cost of equipment and the lack of technical support were barriers to wider adoption. These challenges were particularly noted in the Central Highland region, where open burning remained dominant. Additionally, open burning avoids risks to the next crop caused by wildfire (Figure 6.6).

[5] In this chapter, $ refers to United States dollar.

Figure 6.6. Purpose of the Trash Management Approach



Source: Author's analysis, 2024.

6.3.3 Respondents' Opinions about Problems Caused by Crop Burning

Table 6.1 shows the problems caused by crop burning. Farmers strongly agreed that burning cane trash negatively impacts the environment (100%). Key concerns identified were soil degradation (33.5%), air pollution (32.3%), and health problems (16.3%). The indirect effect of crop burning is that 3.9% of the respondents mentioned reduced crop yields and increased fertiliser application (13.6%).

Table 6.1. Responents' Views on Problems Caused by Crop Burning

Problem	Responses	
	N	%
Impacts on land and forest	0	0.0
Soil quality	86	33.5
High fertiliser application	35	13.6
Inducing wildfires	0	0.0
Destroy ecosystems	0	0.0
Air pollution	83	32.3
Low crop yield	10	3.9
Negative effect on health	42	16.3
Greenhouse gas emissions	1	0.4

Loss of valuable biomass	0	0.0
Others	0	0.0
I do not think it induces problems at all	0	0.0
Total	**257**	**100.0**

N = number or respondents.
Source: Author's analysis, 2024.

Most respondents supported reducing cane trash burning as a sustainable alternative. About 61.9% of respondents expressed concerns about its impact on cultivation practices. Additional barriers included the cost of alternative methods (4.0%) and resistance to changing conventional habits (7.1%). Farmers also identified fears of wildfires (27.0%) as a potential challenge when cane trash is mulched in the field (Table 6.2).

Table 6.2. Respondents' Concerns about Reducing Crop Burning

Concern	Responses	
	N	%
Change from conventional ways	9	7.1
Additional costs for alternative ways to crop burning	5	4.0
Effect on cultivation	78	61.9
Others (Being concerned that it may cause wildfire)	34	27.0
Total	**126**	**100**

N = number or respondents.
Source: Author's analysis, 2024.

During production, all sugar mills invest directly in farmers' land preparation fees and cane seedlings via buy-back contracts. Additionally, fertiliser is an annual investment that ensures nutrients for sugarcane crops. All investments are deducted when the farmer supplies cane. Therefore, farmers cultivating sugarcane do not have demand credit from commercial banks, which is a key policy that gives sugarcane an enhanced competitive advantage over other crops. However, farmers and sugar mills have not received any financial support from the government to reduce cane trash burning in Viet Nam. The study highlights that a small group of farmers require subsidies (27.8%), a few farmers need access to credit with favourable interest to buy their own machinery equipment (2.1%), and the rest of the group does not expect financial support (70.1%) (Table 6.3).

Table 6.3. Financial Support Respondents Receive for Reducing Crop Burning

Kind of Financial Support	Responses	
	N	%
Subsidies	27	27.8
Loan/access to credit	2	2.1
Tax incentive	0	0.0
Do not need any support	68	70.1
Others	0	0.0
Total	**97**	**100**

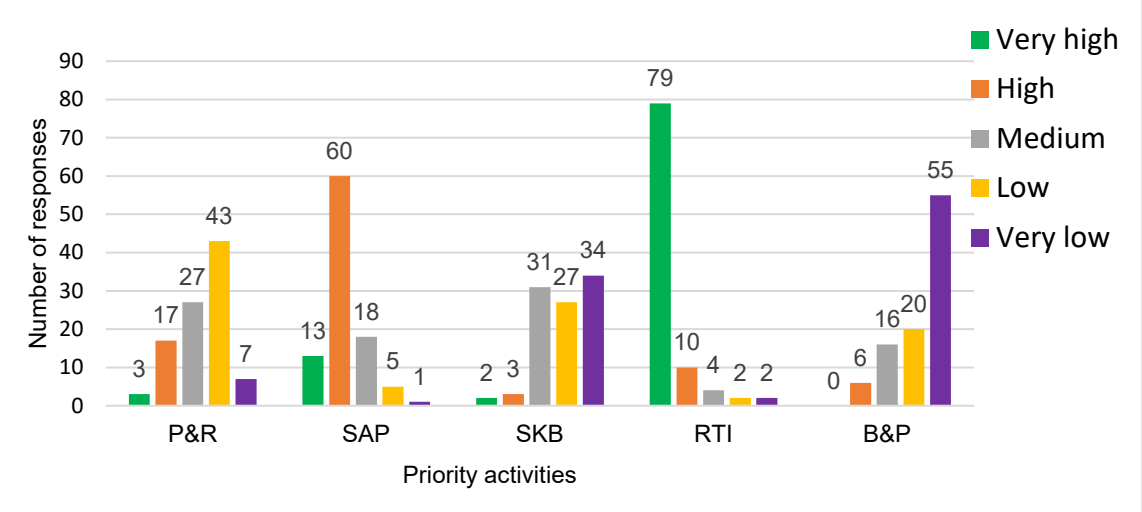
N = number or respondents.

Source: Author's analysis, 2024.

6.3.4 Respondents' Opinions on Priority Activities to Reduce Crop Burning

This section presents a critical analysis of priorities in sustainable agriculture development. Figure 6.7 shows the ranking result of five key activities in order of perceived importance.

Figure 6.7. Respondents' Views on Priority Activities to Reduce Crop Burning



B&P = co-benefits and prospects for new markets from sustainable agriculture practices; P&R = planning for policy and regulatory; RTI = research and technology innovation; SAP = sustainable agricultural practices; SKB = facilitating skills and knowledge building;.
Source: Author's analysis, 2024.

Fostering research and technology innovation emerged as the main issue, with 79% of respondents ranking it as the top priority. This strong consensus is reflected in its narrow range of 1, indicating high agreement amongst participants.

Promoting sustainable agricultural practices secured a solid second place, with 60% of respondents ranking it as the second-most important activity. Its range of 2 suggests relatively consistent views on its significance.

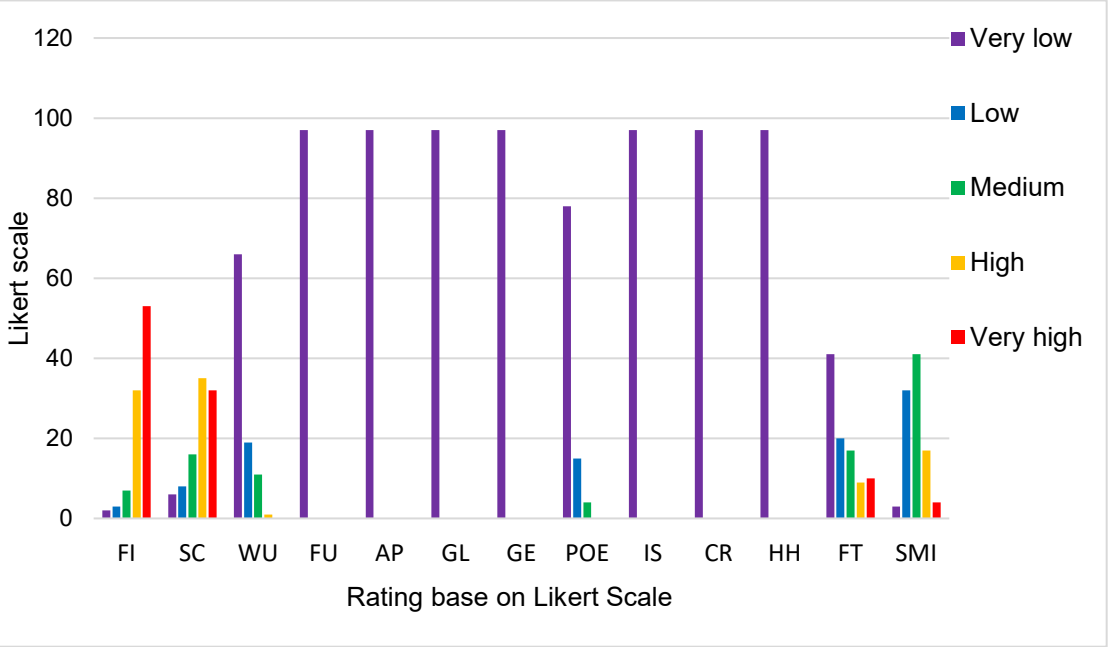
The remaining activities received more varied rankings. Planning for policy and regulatory systems showed a tendency towards middle rankings, while facilitating skills and knowledge building have a broader distribution of priorities. Creating co-benefits and prospects for new markets from sustainable agriculture practices was predominantly viewed as the lowest priority, with 55% ranking it fifth.

This prioritisation provides valuable insights into stakeholders' perspectives on the most effective approaches for advancing sustainable agriculture, highlighting a strong emphasis on innovation and practical implementation of sustainable practices.

Figure 6.8 displays survey results using a Likert scale from 1 (lowest importance) to 5 (highest importance) to show the factors influencing farmers' decision-making in agricultural practices. Sugarcane is the dominant crop and main income of households in the Central Highland and South Coastal regions. Therefore, financial income emerges as the most influential factor, with a high mean score of 4.35. Soil condition follows as the second-most important consideration, depending on soil character which is suitable for sugarcane cultivation. Whereas several factors including water-use efficiency, fertiliser use efficiency, air pollution, carbon emissions, government legislation, extension advice, and community rules show minimal variation, with the vast majority of respondents rating them at the lowest level of importance. The factor 'Free time with your family' was a favourite for households that own small agricultural land, while the sugar mills' direct investment had a moderate level of importance to the farmers. Sugar mills invest cane seedling, fertiliser, and a fee for land preparation. The list was ordered as follows: Financial income (5); Soil conditions (4); Free time with your family (3); Sugar Mill investment (2); and rest factors (1).

This data provides crucial insights into the primary drivers of farmers' decision-making processes, highlighting the economic factors and the relatively low perceived importance of environmental and regulatory considerations (Figure 6.8).

Figure 6.8. Factors Influencing Respondents' Decision-Making in Agricultural Practices (Likert scale)



AP = air pollution and carbon emission; CR = community rules; FI = financial income; FU = fertiliser use efficiency; FT = free time with your family; GE = government extension advice; GL = government legislation; HH = human health; IS = international institutes' support; POE = private organisation extension advice; SC = Soil conditions; SMI = sugar mill investment; WU = Water-use efficiency.
Source: Author's analysis, 2024.

6.3.5 Respondents' Awareness of Policies to Reduce Crop Burning

The survey on crop-burning reduction policies revealed some interesting insights. Regarding awareness of policies, nearly 30% of respondents were familiar with the Law on Environmental Protection. However, a striking 70% of respondents did not know any policies aimed at reducing crop burning. Notably, no one mentioned specific penalties or provincial regulations, indicating a gap in the dissemination of detailed policy information (Table 6.4).

Table 6.4. Respondents' Awareness of Crop-Burning Reduction Policies

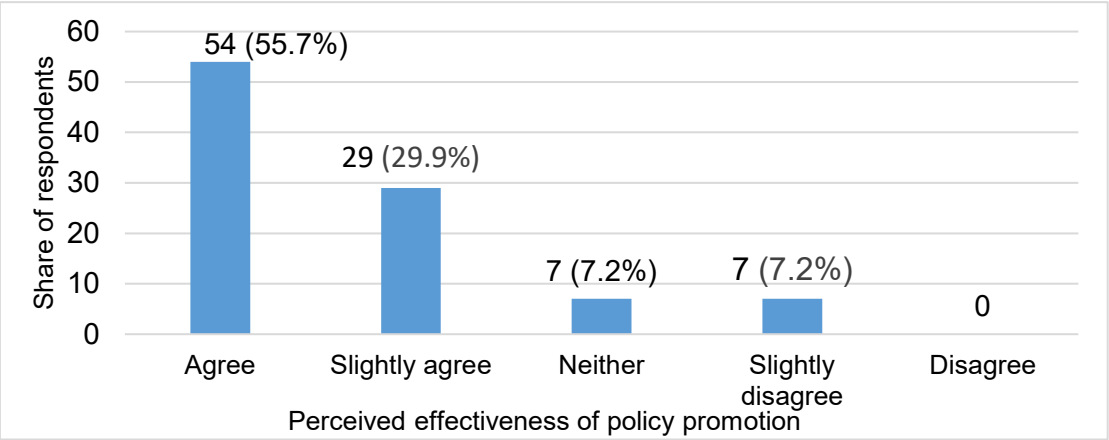
Policy	Responses	
	N	%
The National Assembly hereby promulgates the *Law on Environmental Protection, Law No. 72/2020/QH*	29	29.9
Penalties for administrative environmental protection offences, *Decree No.45/2022/NĐ-CP*	0	0.0
Provincial regulations and bylaw	0	0.0

I do not know any policies to reduce crop burning	68	70.1
Total	**97**	**100.0**

Source: Author's analysis, 2024.

When it comes to policy promotion, the results were more positive. Over half of the respondents (55.7%) agreed that these policies have been well promoted, with an additional 39.9% of respondents slightly agreeing with the promotion efforts. Only 14.4% of respondents were neutral or slightly disagreed, and interestingly, there were no strong disagreements. This suggests that while awareness of specific policies may be low, there is a general sense that information about crop-burning reduction is being disseminated amongst farmers (Figure 6.9).

Figure 6.9. Respondents' Perceptions of the Effectiveness of Promoting Policies to Reduce Crop Burning



Source: Author's analysis, 2024.

All respondents (100%) indicated no awareness of non-formal rules or local wisdom applied to reduce crop burning. This finding highlights the lack of potential opportunity to explore and possibly integrate traditional or community-based approaches into future policy development and implementation.

The result suggests a significant gap in policy awareness and emphasises the need for more effective communication of environmental regulations to farmers. While many feel the existing policies are well promoted, there is room for improvement in reaching all segments of the farming community to ensure a comprehensive understanding of both formal policies and potential informal practices to reduce crop burning.

6.3.6 Respondents Perceptions of Capacity Building and Knowledge-Sharing to Reduce Crop Burning

Based on a Point Factor System with 97 respondents, empowering innovation is considered the primary opportunity, with 42.3% of respondents ranking it as the very high level and 30.9% at high level. This is followed by investment in the future, and learning from peers. Bridging the knowledge gap, leveraging local knowledge, and spreading awareness beyond the farm are not significant issues to promote cane trash burning reduction (Figure 6.10; Table 6.5).

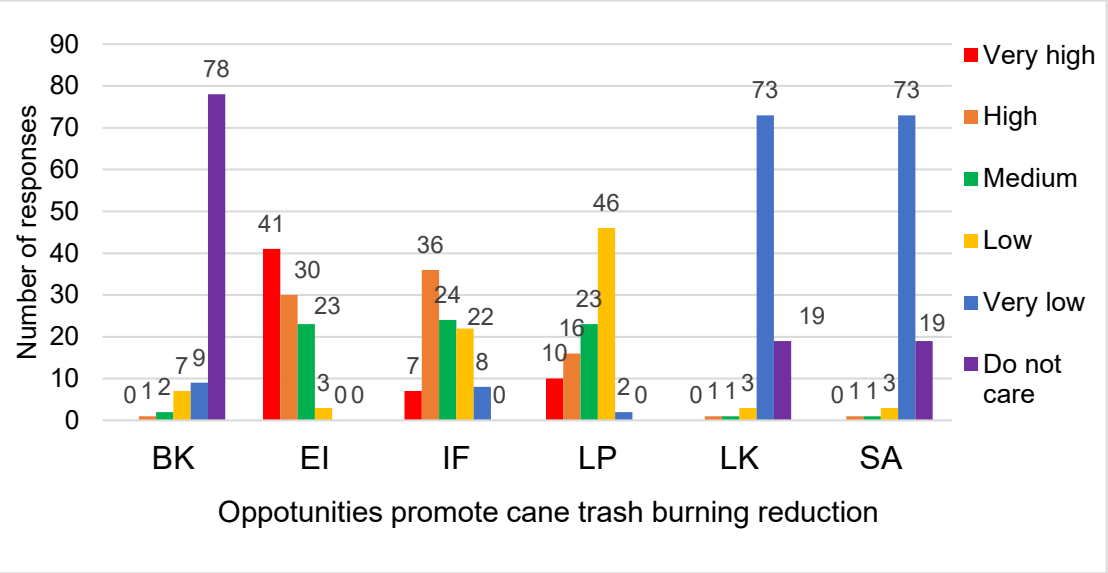
The results indicate that many farmers prefer to make their own decisions rather than rely on local authority policies on cane trash management. Moreover, they urgently need specialised equipment for cutting trash to accelerate decomposition.

Table 6.5. Respondents' Perceptions of Opportunities to Enable Farmers to Promote a Reduction in Crop Burning

Oppor-tunities	Degree rating						Total Respon - dents	Total points
	Very high	High	Mediu m	Low	Very low	Do not care		
	6	5	4	3	2	1		
BK	0	1	2	7	9	78	97	130
EI	41	30	23	3	0	0	97	497
IF	7	36	24	22	8	0	97	400
LP	10	16	23	46	2	0	97	374
LK	0	1	1	3	73	19	97	183
SA	0	1	1	3	73	19	97	183

BK = bridging the knowledge gap; EI = empowering innovation; IF = investment in the future; LP = learning from peers; LK = leveraging local knowledge; SA = spreading awareness beyond the farm.
Source: Author's analysis, 2024.

Figure 6.10. Respondents' Perceptions of Opportunities to Enable Farmers to Promote a Reduction in Crop Burning

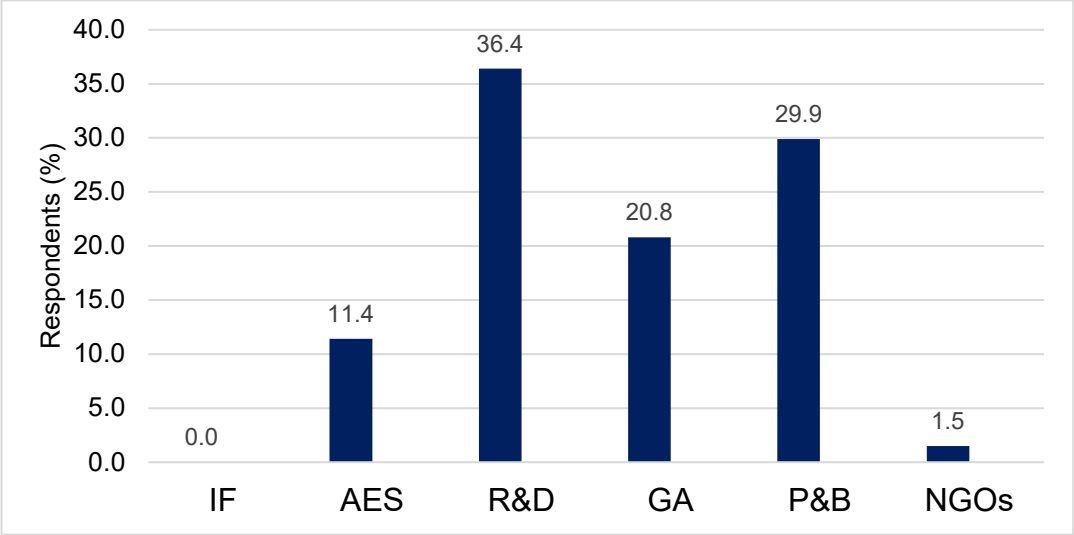


BK = bridging the knowledge gap; EI = empowering innovation; IF = investment in the future; LP = learning from peers; LK = leveraging local knowledge; SA = spreading awareness beyond the farm.
Source: Author's analysis, 2024.

6.3.7 Respondents Attitudes to the Involvement of Stakeholders in Land Management

Figure 6.11 shows that all surveyed farmers are aware of their direct involvement in agriculture and land management. The Government of Viet Nam allows farmers to own agricultural land, and they have the right to select any crop on their land. Therefore, they do not expect 'Individual farmers or farmer groups' who guide them in land management activities. There are expectations for involvement from other stakeholders, with research institutions (36.4%), and private sector and business communities (29.9%) being the most anticipated co-operations. Many farmers desire advanced technology with competitive cost compared with current methods.

Figure 6.11. Expected Partner Institutions and Co-operation Activities: Co-operation Activities for Farmers

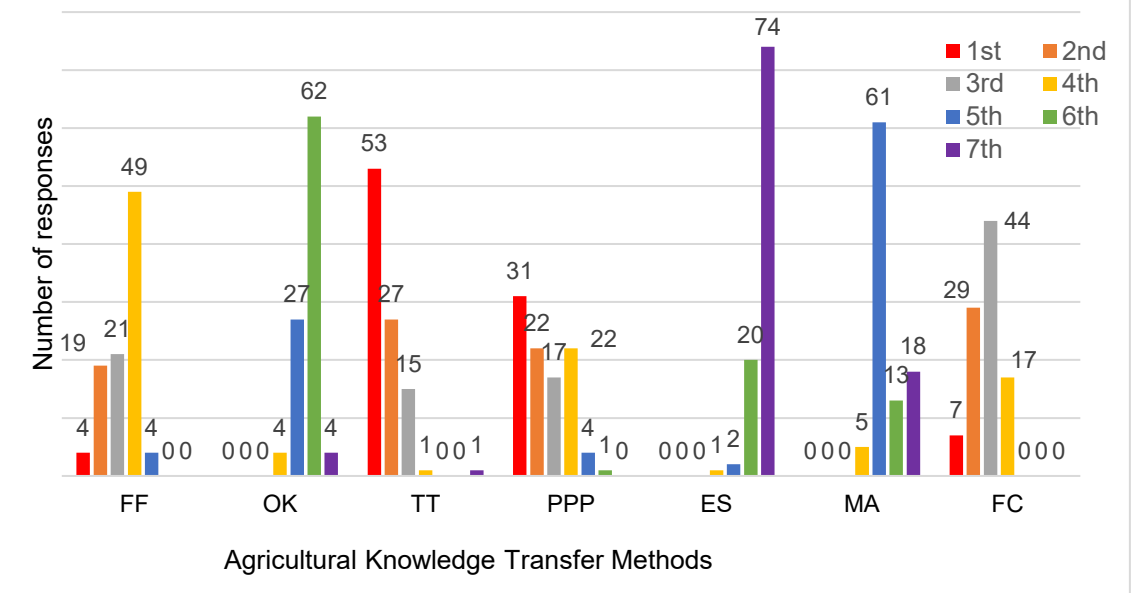


AES = agricultural extension service providers that are involved in the training programmes and demonstration sites; GA = government agencies that are responsible for developing regulatory frameworks and policies for reducing crop-burning practices; IF = individual farmers or farmer groups that are directly involved in agriculture and land management activities; P&B = private sector and business communities that could cater to technology and market creation to support the reduction of crop-burning practices; R&D = research institutions that are developing technologies for reducing the crop-burning practices; NGOs = civil society groups, non-governmental organisations and local communities that contribute to public awareness and mobilisation of sustainable agricultural practices.
Source: Author's analysis, 2024.

Building on these expectations for external support, Figure 6.12 illustrates farmers' preferences for programmes and mechanisms that could strengthen efforts to reduce crop burning. Technology transfer and adaptation (TT) emerged as the most preferred option, with 53 ranking it as the first priority. Public–private partnerships (PPP) and financial incentive mechanisms (FC) also rank highly.

In contrast, the joint enforcement strategies (ES) programme is the least preferred. The data reveals that adoptable technology will spread rapidly nationwide. Additionally, public–private partnerships that combine financial incentive mechanisms will promote developing technology. Overall, the ranking order for preferred programmes is technology transfer and adaptation (TT) (No.1); public–private partnerships (PPP) (No.2); financial incentive mechanisms (FC) (No.3); farmer-to-farmer exchange (FF) (No.4); market access for sustainable products and services (MA)(No.5); online knowledge hub (OK) (No.6); joint enforcement strategies (ES) (No.7).

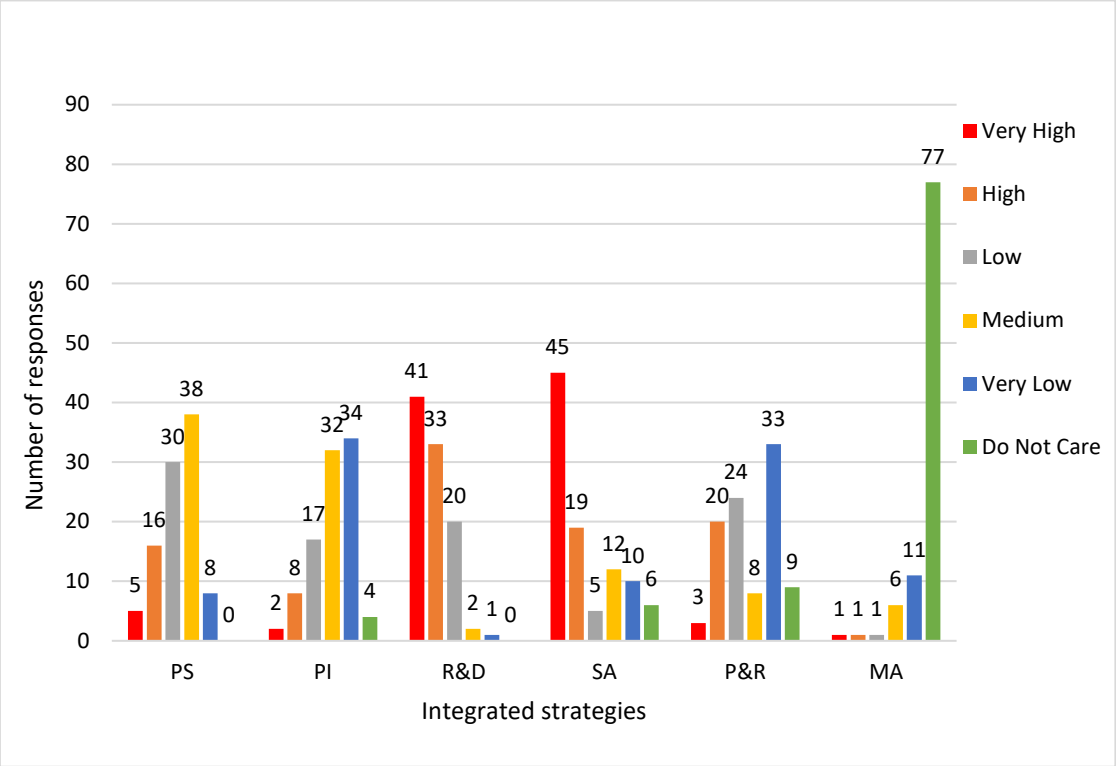
Figure 6.12. Respondents' Preferences for Agricultural Knowledge Transfer Methods



ES = joint enforcement strategies; FC = financial incentive mechanisms; FF = farmer-to-farmer exchanges; MA = market access for sustainable products and services; OK = online knowledge hub; PPP = public–private partnerships; TT = technology transfer and adaptation.
Source: Author's analysis, 2024.

Figure 6.13 outlines integrated strategies for sustainable agriculture. Stakeholder engagement and awareness (SA), along with research and development (R&D) are the top priorities. Market access for new products and services (MA) is consistently ranked as the lowest priority. The ranking order is research and development (R&D) (No.1); stakeholder engagement and awareness (SA) (No.2); new products and services (PS) (No.3); policy and regulation (P&R) (No.4); providing incentives and support to sustainable agricultural practice (PI) (No.5); market access for sustainable products and services (MA) (No.6). These findings highlight the importance of farmers' awareness, technological innovation, and stakeholder engagement in promoting sustainable agricultural practices.

Figure 6.13. Respondents' Preferences for Integrated Strategies to Reduce Crop Burning



MA = market access for new products and services; P&R = policy and regulation; PI = providing incentives and support to sustainable agricultural practice; PS = promoting sustainable agricultural practice; R&D = research and development; SA = stakeholder engagement and awareness.
Source: Author's analysis, 2024.

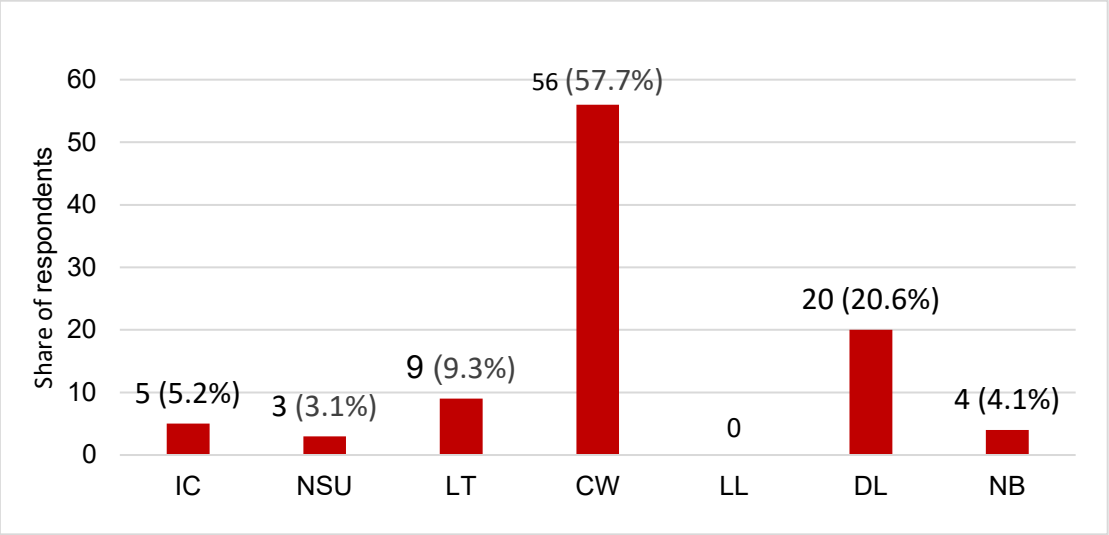
6.3.8 Respondents' Attitudes to the Use of Technology to Reduce Crop Burning

Currently, there is no technology being implemented for reducing cane trash burning or to support the utilisation of cane trash. Therefore, approximately 79.4% of respondents, expressed an urgent need for a residue collection system. When cane trash is baled, it can be utilised for power generation. The second-most anticipated solution is the installation of machinery (for example, trash-cutting equipment) supported by 18.5% of the respondents. The practice of shredding the trash into small pieces causes it to decay more quickly and helps minimise the risk of wildfire. Only a small number of farmers (2.1%) agree with removing cane trash from cane fields without burning and all farmers have no idea about schemes to valorise cane trash.

Many farmers consider open burning the most effective and cost-efficient way to clear land, so the major challenge is changing the conventional way, which accounts for 57.7% of respondents. Furthermore, sugarcane is mainly planted in hilly areas, so it is difficult to apply new techniques in cane trash management,

such as chopping and burying in soil or shredding for 20.6% of respondents. In Viet Nam, sugarcane is mainly cultivated in dry land. Therefore, chopping and burying cane trash in soil is not economic. Over 90% of the cane area is harvested manually, and the remaining cane stubble in the field should be removed after harvesting. Using stubble-shaving and shredding equipment can damage cane roots and cause poor re-germination on the next crop, especially in sandy-loam soil. Other barriers, which are not significant concerns, are detailed in Figure 6.14.

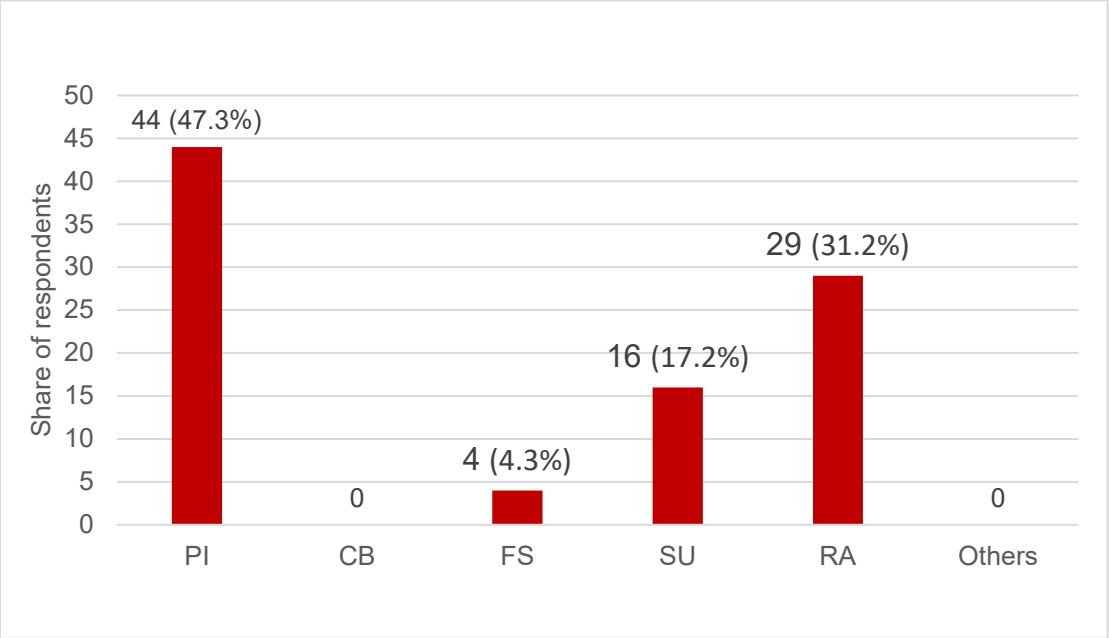
Figure 6.14. Respondents' Perceptions of Barriers to Installing New Technologies



CW = conventional ways are easier than installing new technologies; DL = difficulty to learn new technologies; IC = increasing cost; LT = less incentive to install new technologies; LL = lack of labour; NB = no barriers; NSU = no local scheme to utilise residues.
Source: Author's analysis, 2024.

It is known that open burning cane trash in the field causes many negative issues. Therefore, the most likely solution is pilot instalments and scaling up the process to use cane trash effectively, which accounts for 47.3% of respondents. This is followed by activities for raising awareness (31.2% of respondents), and local schemes for utilising residues (17.2% of respondents). Meanwhile, financial support is not a major issue as most farmers do not consider it to be one. Capacity building and knowledge-sharing about reducing trash burning are also not priorities.

Figure 6.15. Respondents' Perceptions of Solutions to Promote the Implementation of New Technologies



CB = capacity building and knowledge-sharing; FS = financial support; PI = pilot instalment and scaling-up process; RA = activities for raising awareness of crop-burning reduction; SU = local scheme for utilising residues.
Source: Author's analysis, 2024.

Farmers proposed several solutions to reduce crop burning, with pilot installations of new technologies (PI) (47.3%) and raising awareness campaigns(RA) (31.2%) being the most recommended. Local schemes for utilising cane trash (SU) (17.2%) is also highlighted as a necessary measure to encourage sustainable practices, and financial support through subsidies (FS)(4.3%) is an expected solution (Figure 6.15).

6.4 Conclusion

The findings demonstrate that cane trash burning remains a significant issue in Viet Nam, with widespread environmental and agricultural impacts. Sustainable alternatives, such as vegetative mulching and shredding, have proven benefits but face barriers such as the cost of machinery, technical knowledge, and natural conditions.

An integrated approach is required to address these challenges. Government agencies should focus on providing financial incentives, issuing policy frameworks, and offering capacity building programmes, while private companies and research institutions must work together to create affordable, effective technologies. Research institutions were also identified as key players in innovating cost-effective solutions for cane trash management. Pilot projects and awareness

campaigns can facilitate the transition to sustainable cane trash management practices.

By fostering collaboration amongst farmers, stakeholders, and policymakers, Viet Nam can achieve environmentally friendly and economically viable solutions for cane trash management, ensuring long-term benefits for both agriculture and the broader community.

References

Chandel, A.K., S.S. da Silva, W. Carvalho, and O.V. Singh (2012), 'Sugarcane Bagasse and Leaves: Foreseeable Biomass of Biofuel and Bio-Product', *Journal of Chemical Technology and Biotechnology*, 87(1), p.p. 11–20. https://doi.org/10.1002/jctb.2742Digital Object Identifier (DOI)

Kim Oanh , N.T., D.A. Pernmadi, N.P. Dong, and D.A. Nguyet (2018), 'Emission of Toxic Air Pollutants and Greenhouse Gases from Crop Residue Open Burning in Southeast Asia', *Land-Atmospheric Research Applications in South and Southeast Asia*. Cham: Springer Nature Link. https://doi.org/10.1007/978-3-319-67474-2_3

Nakhla, D.A., Y.I. Mahmoud, and S.E. Haggar (2017), 'Production of Compost and Organic Fertilizer from Sugarcane Residues'. *Advances in Ecological and Environmental Research*, pp.69–89. http://www.ss-pub.org/wp-content/uploads/2017/02/AEER2016091701.pdf

Seebaluck, V. and D. Seerutum (2009), 'Utilisation of Sugarcane Agricultural Residues: Electricity Production and Climate Mitigation', *Progress in Industrial Ecology, an International Journal*, 6(2), pp.168–84. https://doi.org/10.1504/PIE.2009.029081

Suma, R. and C.M. Savitha (2015), 'Integrated Sugarcane Trash Management: A Novel Technology for Sustainable Soil Health and Sugarcane Yield'. *Advances in Crop Science and Technology*, 3(1), pp.1-4. https://doi.org/10.4172/2329-8863.1000160

Yadav, R.L., S.R. Prasad, R. Singh, and V.K. Srivastara (1994), 'Recycling Sugarcane Trash to Conserve Soil Organic Carbon for Sustaining Yield of Successive Ratoon Crops in Sugarcane'. *Bioresource Technology*, 49(3), pp.231–35.

Chapter 7
Conclusion and Recommendations

Kentaro Yamada and Siti Mustaqimatud Diyanah

The study was conducted in four Association of Southeast Asian Nations (ASEAN) Member States, namely Indonesia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam. The study identified crop-burning activities from four different crops: oil palm, cassava, rice, and sugarcane. This report summarises the practices to reduce crop burning in each country, to share the outputs amongst ASEAN Member States (AMSs), and to support the implementation of the *ASEAN Guidelines on the Reduction of Crop Burning*. The earlier chapters shared general findings of crop-burning activities and country-specific findings, including potential solutions and recommendations. The final chapter brings them together and outlines key suggestions for reducing crop-burning activities at national and regional levels.

7.1 Conclusion

7.1.1 Crop-Burning Practices

- Indonesia. Burning activity is used for land clearing. Most of the respondents in the study avoid land burning before starting plantation. This indicates a strong awareness of environmental sustainability, soil health, and the fire risks that threaten land and crop productivity. Land burning is also a major driver of large-scale forest fires, particularly in peatland areas.
- Lao PDR. Cassava is an important cash crop in Lao PDR. However, the study showed crop burning remains a common practice amongst farmers for land clearing and postharvest residue management. Some farmers perceive that residue burning contributes to soil nutrient replenishment and aids in controlling pests and diseases affecting newly planted crops.
- Thailand. In Thailand, open burning remains the predominant method of rice straw residue management. Burning the residue is also widely used by farmers as an agronomic tool for weed control. Farmers are hesitant to apply alternative technologies for crop residue management due to the additional cost of adoption.

- Viet Nam. Burning the sugarcane's postharvest residue remains a common practice in Viet Nam. Many farmers in Viet Nam consider that burning the residue is the easiest and cheapest way to dispose of it because alternatives will bring additional burdens to the farming process. Open burning is used for land preparation, replanting in the next cycle, and for removing pests and disease.

7.1.2 Crop Residue Management and Existing Technologies to Reduce Crop Burning

Crop residue management varies depending on the type of crops, geographical characteristics, and the availability of technologies. The study findings highlight the existing crop residue management in Indonesia, Lao PDR, Thailand, and Viet Nam.

- Indonesia: Oil Palm. The land-clearing process for the early stage of oil palm plantation in Indonesia primarily involves felling trees, followed by intercropping with rubber, and utilising heavy machinery for large-scale farmers. For handling oil palm crop residue, most of the farmers rely on manual methods or chainsaws, while only a few, mainly large-scale farmers, use mechanised equipment. The crop residue will be used for mulch or compost. Another approach involves processing the trunks into bioenergy products such as bioethanol, bio briquettes, or biogas, while they can also be utilised as raw material for animal feed production. The result of the study showed that most of the respondents applied more environmentally friendly traditional methods.

  Respondents are aware that there are existing technologies for reducing crop burning. Farmers highlighted the importance of access to installation-based agricultural machinery to facilitate residue management and land preparation without open burning.

- Lao PDR: Cassava. Existing technology for reducing crop residue in Lao PDR for cassava production includes the removal of residue from farmland without burning, followed by the installation of machinery on farms that empowers farmers to manage and utilise cassava residues for composting and biochar production. Farmers have limited awareness of systems for residue collection and the mechanisms for residue valorisation. Technologies that facilitates crop residue removal from farmland in Lao PDR are highly desired by the farmers, considering the geographic constraints of the farmland and the need to ensure the long-term sustainability of farming systems.

- Thailand: Rice. Rice straw residue management in Thailand differs between the wet season and the dry season. During the wet season, the farmers prefer to chop the straw and incorporate it into the field. Other methods to dispose of the crop residue include using it as feedstock for livestock, open-field burning of scattered straw, or controlled burning of straw piles. In addition, farmers earn additional income by selling straw bales. In the dry seasons, more farmers tend to chop the straw and incorporate it into the field, sell the straw bales, practise open-field burning of scattered straw, or controlled burning of straw piles. The findings highlight the diverse strategies employed by farmers in response to economic, agronomic, and environmental drivers, while also revealing opportunities to advance more sustainable alternatives.
- Viet Nam: Sugarcane. In Viet Nam, cane residue is mainly managed through open burning and, to some extent, vegetative mulching, whereas shredding is still at an early stage and applied only on a small scale. Open burning continues to be the most common method for land preparation. Amongst the alternative residue management practices, vegetative mulching is the most widely practised by farmers. However, the high cost of equipment, worsened by the lack of technical support, constrained broader adoption of alternative technologies.

7.1.3 Challenges to Reduce Crop Burning

There are key obstacles to achieve a reduction in crop burning, including limited knowledge, high implementation costs and perceived risks of alternative technologies, entrenched local traditions, limited access to markets and finance, and insufficient policy support.

- High cost. High costs associated with the adoption of new technologies often hinder farmers' willingness to transition toward more sustainable practices. The initial investment (upfront cost) in tools or new technology can be a financial burden for farmers.
- Limited access. Agricultural lands are often in remote areas where farmers face limited access to technology, while underdeveloped infrastructure exacerbates these constraints.
- Limited knowledge. The average low education level of farmers may hinder their information-processing capacity. It will constrain the diffusion and uptake of alternative initiatives.
- Limited access to finance and markets. Smallholder farmers often face limitations in access to finance. A lack of incentives and subsidies increases

farmers' vulnerability and heightens uncertainty in the face of risks, as the adoption of new technology causes a financial burden to farmers. Products of alternative technology need a market. Direct market access for alternative products remains challenging for farmers, while government intervention to enhance market connectivity is still limited.

- Insufficient policy support. Some of the countries in the study have introduced policies and regulations; however, challenges in implementation and gaps in regulatory frameworks have allowed open burning practices to remain.

7.1.4 Supporting Policies and Regulations in the Reduction of Crop Burning

There are policies and regulations that support the reduction of crop burning, at both the regional and national levels. During the 46th Meeting of ASEAN Ministers on Agriculture and Forestry (AMAF), the leaders adopted the *ASEAN Guidelines on the Reduction of Crop Burning* The guidelines serve as guidance for AMSs that offer a clear path forward for achieving a carbon-neutral future through sustainable agricultural practices. The guidelines highlight the importance of collaborative efforts for the reduction of crop burning in ASEAN.

At the national level, some countries have specific policies to address crop burning. For instance, Indonesia's 'zero-burning' policy, implemented since 2014, has contributed significantly to reducing land-burning practices. Indonesia also has a Regulation of the Minister of Agriculture of the Republic of Indonesia No. 47 of 2014 on the Brigade and Implementation Guidelines for the Prevention and Control of Land and Plantation Fires and Regulation of the Director General of Climate Change Control No. 12 of 2020 on the Standard Operating Procedures for Forest and Land Fire Control Activities. However, these policies and regulations are a challenge for smallholder farmers, who need a transition to alternative technology that is often more expensive and time-consuming. In Viet Nam, the government issued the Law on Environmental Protection, Law No. 72/2020/QH and Penalties for Administrative Environmental Protection Offences, Decree No.45/2022/NĐ-CP.

Indirect crop-burning reduction policies have also been implemented in several countries. In Lao PDR, existing local regulations prohibiting slash-and-burn practices are more widely recognised and familiar to farmers.

Thailand has various policies for crop-burning reduction. The Government of Thailand provides comprehensive activities. Ministerial Regulation on the Control of Open Burning B.E. 2555 (2012) provides specific guidelines and controls for open burning activities, including those related to agricultural practices. Thailand also has local regulations to support the efforts on crop-burning reduction.

Even though various policies and regulations exist, the study highlighted less awareness amongst respondents for related policies and regulations. The significant gap in policy awareness underscores the necessity of effective communication strategies to facilitate the diffusion of existing policies, ensuring that all segments of the farming community develop a comprehensive understanding of both formal regulations and informal practices aimed at reducing crop burning.

7.2 Solutions and Recommendations

Drawing from the ideas in the country reports, the following initiatives could be thoroughly considered to address challenges in the reduction of crop burning in ASEAN.

(i) Ecosystem protection

- Restore ecosystems and prevent land fires. Restoration programmes could be focused on soil rehabilitation, biodiversity conservation and promoting more environmentally friendly activities. This requires integrating restoration targets into agricultural and environmental policies, supported by financial incentives, capacity building programmes, and active participation of local communities and private stakeholders.

  The enforcement of stricter regulations to prohibit open burning, including practices such as slash-and-burn for land clearing, is essential to effectively prevent fires and reduce environmental degradation. Preventive measures such as canal blocking and the installation of bore wells should be promoted, as these interventions can play a critical role in reducing the risk of fires.

- Support applicable, affordable, and sustainable initiatives for residue management. Sustainable alternatives to open burning are increasingly recognised as essential for improving agricultural and environmental outcomes. Several existing crop residue management practices can be considered, including postharvest residue incorporation, baling, composting, and utilising residues as livestock feed. Further, smallholder farmers in ASEAN require practical technologies that do not impose additional financial burdens on their farming activities. Alternative technologies need to provide potential co-benefits from their activity, with innovations such as biochar offering promising opportunities to enhance adoption across the region. Biochar can be expanded into commercialisation and returned to the soil for regenerating soil fertility.

- Provide pilot projects. Pilot projects and demonstration sites should be established to showcase environmentally friendly alternative technologies and encourage their broader adoption.
- Adopt monitoring and evaluation tools. Adoption of advanced monitoring tools, such as drones and satellite technologies, can strengthen surveillance and assessment of restoration programme implementation and ensure accountability.

(ii) Improve literacy and capacity building

- Increase farmer awareness and behavioural change. Although a reduction in crop burning will provide a better environment, farmers tend to be conservative, considering the cost and other related matters when adopting alternative technologies. Limited literacy on crop-burning issues and the insufficient availability of programmes designed to enhance farmers' understanding and awareness worsen the adoption rate of more environmentally friendly technologies.
- Produce training and capacity building programmes. These can enhance farmers' understanding of the impact of the alternative technologies. Furthermore, sustained agricultural extension services, coupled with peer-to-peer learning and knowledge exchange amongst farmers who have successfully adopted these innovations, can play a pivotal role in accelerating widespread adoption.
- Create knowledge-sharing programmes. Knowledge-sharing initiatives can enhance farmers' awareness of the negative impact of land and crop residue burning. The programmes can emphasise the environmental and health impacts of crop burning while promoting sustainable alternatives and fostering behavioural change to reduce reliance on burning practices. Agricultural extension services and related institutions need to adopt more proactive approaches in disseminating clear and accessible information to farmers on eco-friendly alternatives, thereby facilitating knowledge transfer and supporting the adoption of sustainable agriculture practices. Digital data and information systems can serve as an integrated platform that connects farmers, governments, and relevant stakeholders, enabling the exchange of data, knowledge, and best practices for reducing crop burning.

(iii) Align policy and regulations

- Strengthen enforcements and incentives. Policy and regulatory frameworks are the first and most important step for the reduction of crop burning. Governments need to strengthen law enforcement and impose strict sanctions for regulatory offences, while also guiding smallholders who may not have access to alternative technologies, as well as providing incentives for farmers who adopt environmentally friendly practices.
- Increase policy awareness and co-ordination. Additionally, efforts to increase policy awareness of both formal and informal policies are necessary. These efforts require collaborative engagement between government institutions and relevant stakeholders, with active participation from the private sector. The alignment of policy and regulatory frameworks within national to local governance levels is essential to facilitate effective and coherent implementation.

(iv) Increase access to finance and market

- Reduce cost barriers. High upfront costs associated with the adoption of new technologies often hinder farmers' willingness to transition toward more sustainable practices. Reducing the high initial investment through subsidies or financial assistance is vital to facilitate technology adoption. In parallel, policy frameworks should be reinforced by improving farmers' access to credit and broadening distribution channels for eco-friendly technologies, with a particular focus on smallholders who remain the most resource-constrained. Providing subsidies or incentives is crucial to reducing financial constraints for small-scale farmers with limited access to technology and capital, particularly in the early stage of adaptation.
- Increase access to machinery and technology. The government, in collaboration with relevant stakeholders, could enhance access to affordable residue-processing machinery, establish transportation and collection mechanisms, and provide funding for small-scale initiatives that promote alternative technologies such as biochar and biogas.
- Develop markets and incentives. Products of alternative technology need a market. This highlights the role of multi-stakeholder collaboration in fostering markets for sustainable agricultural products and facilitating the development of carbon credit markets. Appropriate financial mechanisms should be established that reflect the unique conditions of AMSs and promote private sector engagement in efforts to reduce crop burning and to

attract private sector investment in crop-burning reduction initiatives.

(v) Enhancement of public–private partnerships (PPPs) and all related stakeholders

- Increase public–private partnerships. The collaboration between the public and private sectors, including all related stakeholders, will help ensure that policies and regulations are well implemented. The partnerships are expected to stimulate investment in infrastructure and technology that underpin sustainable agricultural practices. Each stakeholder plays a critical role in translating policies into actionable measures to ensure their effective implementation at the farmer level.
- Clarify roles for government and the private sector. The government serves as the primary actor in formulating policies and regulations aimed at reducing crop burning. Research institutions develop environmentally friendly technologies to reduce plant-burning practices. The engagement of local communities, including farmer co-operatives, facilitates the transfer of knowledge and technology from policymakers and the private sector, thereby contributing to the reduction of crop burning. Another key player in reducing land-burning practices is the private sector and business community, which can contribute to providing greater investment in technology, facilitating access to finance, and expanding market opportunities for the alternative products. The role of civil society groups, NGOs, and local communities is also expected to raise awareness and promote sustainable agricultural practices through the reduction of crop-burning activities.
- Create joint initiatives and incentives. Joint initiatives between the government and related stakeholders that balance policy, technological innovation, and market access to create a comprehensive framework for reducing crop burning. This includes providing training and extension programmes to enhance farmers' skills, particularly in adopting modern agricultural technologies. Mentorship and incentives programmes could also attract engagement, including young farmers.

(vi) Monitoring and evaluation

- Develop tracking frameworks. The efforts in the reduction of crop burning require not only the implementation of alternative practices but also the development of robust monitoring and evaluation mechanisms. It is difficult to assess whether the initiatives are achieving the target for more

sustainable practices without systematic tracking. Monitoring provides information on the level of adoption, while evaluation offers insights to enhance effectiveness, improve efficiency, and ensure steady progress in the implementation of policies and programmes Developing a comprehensive monitoring and evaluation framework is essential to ensure the effectiveness of crop-burning reduction initiatives, ensure compliance with regulations, and inform evidence-based policy adjustments.

Appendix

Example of a survey questionnaire used in the Thailand case study

Location _____
No. respondent _____
Enumerator name _____
Interview date _____

Questionnaire for activities to reduce crop burning in a field

Background and Objective

Crop burning has emerged as a significant environmental, economic and public concern across the ASEAN countries. This is associated with agricultural burning by using fire for vegetation management in open areas such as farmland, orchards, rangelands, and forests. Agricultural burning is a type of open burning where the entire crop is deliberately set on fire such as slash-and-burn farming in forest areas, and using fires for land clearing of large fields.

To deliver the comprehensive framework and roadmap for AMS, the Guidelines on the Reduction of Crop Burning are being developed. In line with this activity, case studies for crop-burning reduction in AMS are required to support the implementation of the Guidelines.

In this interview, we would like to survey the actual status of crop burning on farmland. The answers are summarised for each crop and country, and compared with other cases. That will provide common characteristics amongst the cases, which would be transferable to other countries, and specific characteristics. Such results will be expected to support the implementation of the Guidelines and will lead to further promotion of crop-burning reduction in ASEAN countries.

Your participation in this research study is completely voluntary. All data is stored in a password-protected electronic format and can only be accessed by the project team (ERIA -). We respect your trust and protect your privacy, and therefore will never share or present any data and personally identify with any third parties.

We securely store this data until the end of this year, when the research study is over. The final results will be used for programme development purposes only. Therefore, your responses will be confidential. Completing the survey indicates your consent for use of the answers you supply.

If you have any questions about the research study, please contact (*CP of interviewer*).

PART I: RESPONDENT IDENTITY

1.1 **Name:**_____

1.2 **Contact:** Mobile Phone/Line_____

1.3 **Location** (Sub-district, District, Province): _____

1.4 **Gender**: ☐ Male ☐ Female ☐ Not identify

1.5 **Occupation/Job**: ☐ Farmer ☐ Co-operatives ☐ Processor
☐ Distributor ☐ Trade association ☐ Others_____

1.6 **Years in rice farming**:_____

1.7 **Household size**: _____

1.8 **Farm size (ha)**: _____

1.9 **The number of family members working on the farm**: _____

1.10 **Education**:☐ Illiterate ☐ Primary ☐ Secondary ☐ Vocational
☐ Higher (Diploma, Bachelor, Master, Doctor)

1.11 **Member of farmers association:**

☐ Farming co-operative ☐ Rice Community enterprise

☐ GAP☐ Organic farming ☐ OTOP

☐ Smart farmer ☐ Soil doctor group ☐ Sustainable Rice Production (SRP)

☐ Water User Association (WUA) ☐ Seedling production group

☐ Small & Micro Community Enterprise

☐Other, specify_____

1.12 **Access to credit:**

☐ BAAC (Thai bank)☐ Commercial Bank☐ Village Fund☐ Friends

☐ Agricultural extension savings and credit co-operatives

☐ Other, specify

PART II: CURRENT STATUS

2.1 Variety that is used in different seasons (Specified in each commodity)

☐ Khao Dawk Mali 105 ■ Wet Season ■ Dry Season

☐ RD 6 ■ Wet Season ■ Dry Season

☐ RD 10 ■ Wet Season ■ Dry Season

☐ RD15 ■ Wet Season ■ Dry Season

☐ RD 81 ■ Wet Season ■ Dry Season

☐ RD 41 ■ Wet Season ■ Dry Season

☐ RD 47 ■ Wet Season ■ Dry Season

☐ RD 61 ■ Wet Season ■ Dry Season

☐ RD 85 ■ Wet Season ■ Dry Season

☐ Pathum Thani 1 ■ Wet Season ■ Dry Season

☐ Phitsanulok 2 ■ Wet Season ■ Dry Season

☐ Other ■ Wet Season____■ Dry Season _____

2.2 Extension services and support received from the agent:

☐ Sustainable rice farming

☐ Agroforestry

☐ GAP (Good Agricultural Practice)

☐ IPM (Integrated Pest Management)

☐ Crop-Burning reduction technologies

☐ Organic fertiliser

☐ Climate-smart agriculture using advanced technologies and innovation

☐ Other, specify_____

2.3 Did you get extension service related to crop-burning reduction technology so far?

☐ No

☐ Yes, how many times have you received? _____

2.4. What type of burning has been conducted in your field? Select all that apply

☐ Crop residue burning

☐ Weed residue burning

☐ Others (please specify)_____

☐ No experience for burning

2.5 What do you currently do with your rice straw? Please tick ✓ all that apply

Rice straw Management Options	Apply Method		Volume of RS gained		Labour used: Family/ neighbours/ hired		Labour cost		Income induced (THB)	
	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS

Chopped and then incorporated into the paddy during land preparation										
Rolled with a heavy roller to crush the straw into the soil surface										
Burned spread in the field										
Burned in a pile										
Removed from the field for other uses:										
- Feedstock for livestock										
- Composting										
- Mushroom production										
- Vegetative mulch										
- Briquettes for bioenergy										
- Biochar										
Other, specify_____ _____										

WS = wet season cropping, DS = dry season cropping

2.6 Why are you using this approach? _____

2.7 Have you ever incorporated rice straw and stubbles into the fields?

☐ No

☐ Yes, what is the purpose of incorporating rice straw? _____

_____

PART III: OPINIONS BY THE RESPONDENTS

3.1 Does burning (Specific crop) have a positive or negative effect on the environment?☐ Negative ☐ Positive

3.2 What is the problem induced by crop burning? Select all that apply

☐ Impacts on land and forest

☐ Air pollution

☐ Soil quality

☐ Low crop yield

☐ High fertiliser application

☐ Negative effect on health

☐ Inducing wildfires

☐ Greenhouse gas emissions

☐ Destroy ecosystems

☐ Loss of valuable biomass

☐ Others (please specify) _____

☐ I do not think it induces problems at all

3.3 What is your expectation for reducing crop burning? Select all that apply

☐ That would be the possible solution for the issues shown in Q3.2

☐ Utilising residues improves cost/benefit balance.

☐ Others (please specify) _____

3.4 What is your concern for reducing crop burning? Select all that apply

☐ Change from conventional ways

☐ Additional costs for alternative way to crop burning

☐ Effect on the cultivation

☐ Others (please specify) _____

PART IV: ACTIVITIES FOR CROP-BURNING REDUCTION

4.1 What activities should be prioritised? Please rank them

Rank	Activities
	1. Planning for policy and regulatory systems
	2. Promoting sustainable agricultural practices
	3. Facilitating skills and knowledge building
	4. Fostering research and technology innovation
	5. Creating the co-benefits and prospects for new markets from sustainable agriculture practices
	6. Creating the local markets
	7. Creating the local burning management centre
	8. Funding support mechanism

	9. Supporting appropriate machines

4.2 Please rate the following factors based on how important they are to your agricultural decision-making

Factor	Likert scale (1 is lowest)				
	1	2	3	4	5
Financial income					
Soil conditions					
Water-use efficiency					
Fertiliser use efficiency					
Air pollution and carbon emissions					
Government legislation					
Government extension advice					
Private organisation extension advice					
International institutes' support					
Community rules					
Human health					
Free time with your family					
Other, specify _____					

PART V: CROP-BURNING REDUCTION POLICIES

5.1 Are there any regulations in place to control (specific crop) burning?

☐ No☐ Yes

5.2 What policies do you know in aim to reduce crop burning? Select all that apply

☐ Environmental Protection and Promotion Act B.E. 2535 (1992)

☐ Clean Air Act B.E. 2535 (1992)

☐ Royal Decree on Air Quality Management in Residential Areas B.E. 2553 (2010)

☐ Ministerial Regulation on the Control of Open Burning B.E. 2555 (2012)

☐ National Agenda Action Plan Solving the Problem of Dust Pollution (2020)

☐ Climate Change Act. B.E. 2567 (2024)

☐ Local Regulations and Bylaws

5.3 Do you agree that those polices of crop-burning reduction have been well promoted? Select one

■ Agree ■ Slightly agree ■ Neither

■ Slightly disagree ■ Disagree

PART VI: CAPACITY BUILDING AND KNOWLEDGE-SHARING

6.1 Do you know the opportunities for capacity building and knowledge-sharing to promote crop-burning reduction?

■ Yes, Please specify _____

■ No.

6.2 What opportunities do you need to promote crop-burning reduction? Please rank them

Rank	Opportunities
	1. Bridging the knowledge gap
	2. Empowering innovation
	3. Investing in the future
	4. Learning from peers
	5. Leveraging local knowledge
	6. Spreading awareness beyond the farm
	7. Climate Change Fund

PART VII: INVOLVING STAKEHOLDERS

7.1 What co-operation activities do you know and expect? Please tick ✓ all that apply

Know	Expect	Co-operation activities
		1. Individual farmer or farmer group that are directly involved in agriculture and land management activities
		2. Agricultural extension service providers that are involved in the training programmes and demonstration sites
		3. Research institutions that are developing technologies for reducing the crop-burning practices
		4. Government agencies that are responsible for developing regulatory frameworks and policies for reducing crop-burning practices

		5. Private sector and business communities that could cater to technology and market creation to support the reduction of crop-burning practices
		6. Civil society croups, NGOs and local communities that contribute to public awareness and mobilisation of sustainable agricultural practices

7.2 What programmes would you like to prioritise for scaling up the involvement? Please rank them

Rank	Programmes
	1. Farmer-to-farmer exchanges
	2. Online knowledge hub
	3. Technology transfer and adaptation
	4. Public–private partnerships
	5. Joint enforcement strategies
	6. Market access for sustainable products and services
	7. Financial incentive mechanisms

7.3 To promote crop-burning reduction, integrated strategies need to be implemented. What strategies should be prioritised? Please rank them

Rank	Integrated strategies
	1. promoting sustainable agricultural practices
	2. providing incentives and support to sustainable agriculture practices
	3. research and development
	4. stakeholder engagement and awareness
	5. policy and regulation
	6. market access for new products and services

PART VIII: TECHNOLOGIES

8.1 What technologies have been implemented and are expected to be implemented for reducing crop burning and utilising crop residues? Please tick all that apply

Know	Expect	Technologies
		1. Machinery instalment on farmland
		2. System for collecting residues

		3. Scheme to valorise residues
		4. Removal of residues from farmland surface without burning
		5. Others (Please specify _____)

8.2 Do you know recent practices that new technology has been implemented, and how the effect is?

- Yes, Please specify _____
- No, Please describe the effect _____

8.3 What are the barriers to install new technologies for crop-burning reduction? Please select all that apply

☐ Increasing cost ☐ Lack of labours

☐ No local scheme to utilise residues ☐ Difficulty to learn new technologies

☐ Less incentive to install new technologies ☐ No barriers

☐ Conventional ways are easier than installing new technologies

9.4 (For respondents choose except 'No barriers' in Q9.3) What are the possible solutions to promote the implementation of new technologies? Please select all that apply

☐ Pilot instalment and scaling-up process

☐ Capacity building and knowledge-sharing

☐ Financial support

☐ Local scheme for utilising residues

☐ Activity for raising awareness of crop-burning reduction

☐ Others (Please specify _____)