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Reducing the Need to Burn: How Applying Sustainable Agricultural Mechanization in Cambodia can Improve Air Quality

Picture courtesy: Department of Agricultural Engineering, Cambodia

ESCAP
CSAM
Centre for Sustainable Agricultural Mechanization

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TABLE OF CONTENTS

I. INTRODUCTION

Globally 17 billion years of life are lost yearly due to air pollution, with an average of 2.2 years lost per person[1]. In Southeast Asia, air pollution exposure is a particular problem, with 99.9% of the population – around 656 million people – living in regions where fine particulate matter ($PM_{2.5}$) pollution exceeds the WHO guideline level[2,3].

Yearly average $PM_{2.5}$ pollution concentrations in Southeast Asian countries have remained high in recent years, showing relatively limited progress towards clean air (see Figure 1).

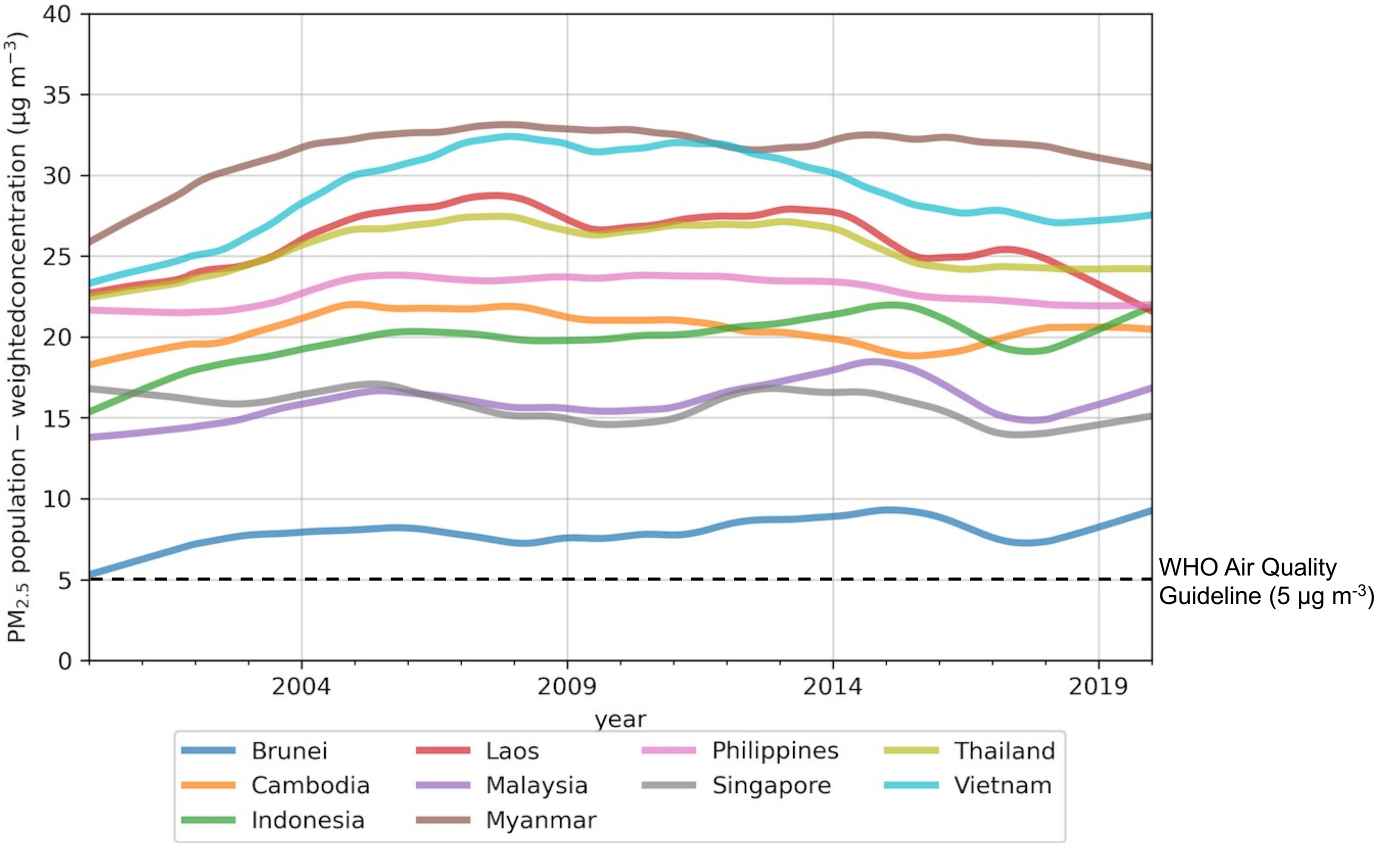

Figure 1. National population-weighted PM2.5 concentrations for Southeast Asian countries between the years 2000 to 2020. Figure was produced using PM2.5 data from van Donkelaar et al.[4] and population data from CIESIN[5].

A major source of PM2.5 exposure in Southeast Asia is open burning of agricultural residues, forest clearance fires, and peatland fires, particularly during burning seasons[6,7,8]. Huge amounts of crop residues are burnt in Southeast Asia every year (see Figure 2). In 2020, the amount of biomass dry matter burnt per square kilometre of agricultural land in Southeast Asia was two times that in North America and mainland China, and comparable to South Asia[9,10]. Exposure to PM2.5 pollution from agricultural and forest fires is associated with adverse health outcomes including morbidity and mortality[11-14]. Preventing these fires in Mainland Southeast Asia could have a substantial human health benefit; reducing regional average PM2.5 exposure by 16% and avoiding around 59,000 premature deaths yearly across the region and southern China[7].

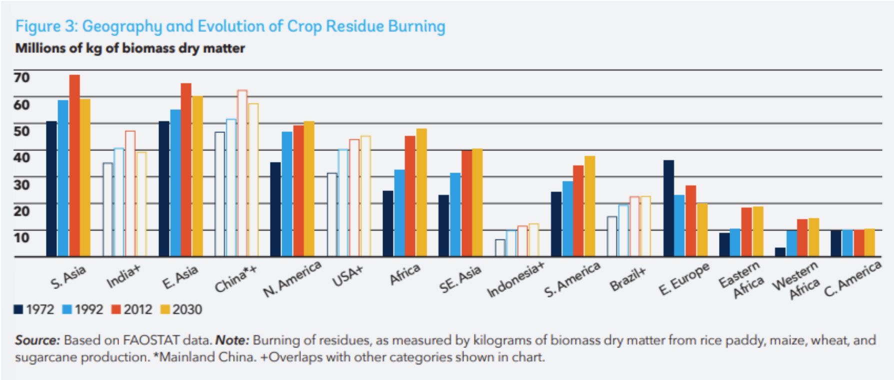

Figure 2. Geography and evolution of crop residue burning.

Open biomass burning practices in Southeast Asia are also a large source of greenhouse gas (GHG) emissions[15,16]. In some burning seasons, the amount of carbon dioxide emitted from these fires have been greater than from yearly fossil fuel emissions in countries such as Germany, Japan, and Indonesia[17].

In addition to increasing GHG emissions and causing adverse effects on air quality and public health, agricultural residue burning can negatively affect soil health, leading to a loss of soil carbon and micro-nutrients, while adversely affecting soil temperature, pH, moisture, and organic matter[18]. Farmlands that have undergone repeated burning generally have reduced soil fertility[19] and higher erosion rates[20], requiring increased use of fertilizer[21]. However, viable no-burn alternatives exist that can provide both environmental and economic benefits to the farmers[22].

Implementation of modern agricultural machinery can promote the transition to sustainable and integrated management of agricultural residues, for example using baler machinery to compress and transport straw as bales for use as livestock feed/bedding, bioenergy, mushroom substrate, or industry material[23]. Once the rice straw has been harvested, using direct seed drill machinery can further benefit the farmer; reducing the amount of seed needed and increasing the seed survivability, even if rainfall is limited, thus improving the resistance of the cropland to climate change. Moreover, with direct seeding the crop matures and can be harvested earlier, allowing more time for the stubble to decompose before the next cropping cycle, thus discouraging burning.

Reducing air pollution from biomass burning in the agricultural sector in Southeast Asia will help countries uphold their commitment to the 2015 Paris Accords and other global conventions and standards to tackle climate change. In addition, agricultural emissions reductions would support the attainment of the targets laid out in the Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty) target 1.4 (poor have equal access to appropriate new technology), SDG 2 (Zero Hunger) target 2.4 (ensure sustainable food production systems, SDG 12 (Responsible Consumption and Production) target 12.2 (promote efficient use of natural resources), and SDG 13 (Climate Action) target 13.1 (strengthening adaptive capacity to climate-related hazards).

II. PROJECT BACKGROUND

A. The CSAM Regional Initiative on Integrated Straw Management

In 2018 the Centre for Sustainable Agricultural Mechanisation (CSAM) of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), with the support of ESCAP's Environment and Development Division, commenced a regional initiative to promote mechanization-based solutions for integrated management of crop straw residue to enable sustainable and climate-smart agriculture. The main objective was to identify, test and adapt innovative agricultural equipment and machinery for alternate uses and sustainable management of straw residue which could reduce farmers' inclination to openly burn this potentially valuable resource, thereby reducing air pollution and GHG emissions from the agricultural sector and preserving soil health. The approach was centred around a circular model (see Figure 3) of straw management within farming communities including use of straw for purposes such as

fertilizer, fodder, substrate for mushroom growing and production of clean energy.

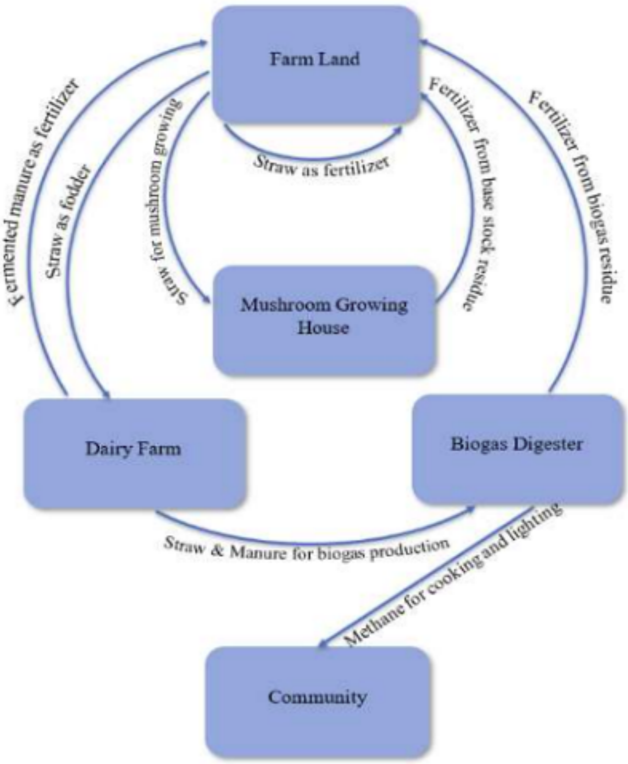

Figure 3. Circular model of straw utilisation.

Following the launch of the regional initiative, positive results were attained via pilot projects implemented in China and Viet Nam in collaboration with national partners, where agricultural machinery was applied and optimized to improve current practices and provide suitable alternatives to burning straw residue that enabled ecological and economic benefits for the farms involved. For instance, the pilot in China demonstrated utilisation of wheat and maize straw as fertilizer, fodder and production of biogas, in-place of burning, whilst increasing crop yields, soil organic matter, and the net income of the local farmers cooperative. The pilot project in Viet Nam demonstrated the yield and quality enhancement benefits from using straw to cultivate mushrooms via an indoor method. Moreover, India, which had already established a large-scale national project to combat straw burning, contributed to the initiative as a knowledge-sharing partner and hosted a study tour in 2019 to demonstrate related machinery and good practices.

In 2021 the regional initiative expanded further to build on lessons learned, with pilot sites in Cambodia, Indonesia, and Nepal. It engaged with the farming communities at pilot sites to first understand their needs through baseline assessments and workshops, then implemented technical interventions by providing training and agricultural machinery/equipment to the local community and documenting the successes and learnings in the real world.

The results of this work have shown how new measures can be applied effectively when directly engaging with local stakeholders to explore contextually suitable approaches and identify machinery that can be adapted to serve their needs.

B. Identifying key areas for interventions

Pinpointing where to apply these interventions involves identifying the areas with greatest fire activity, typically requiring a robust system to monitor and measure burning hotspots and the associated air pollution. ESCAP has been undertaking work to help governments target where interventions are critically needed which has complemented the CSAM regional initiative. This work uses advanced data science practices to build a machine learning model that relies on simple data and the moderate-resolution imaging spectroradiometer (MODIS) satellite images to identify hotspots and make more accurate predictions about policy impacts. This model has been tested across the Asia-Pacific region, along with an in-depth case study done hand-in-hand with the local government in Chiang Mai, Thailand.

Combining this methodological approach with techniques from the CSAM regional initiative can significantly reduce the impact of air pollution by informing farmers and decision-makers of burning hotspots where the need for mechanisation should be prioritized to be most relevant.

C. Pilot on Integrated straw management in Cambodia

This Brief on integrated straw management in Cambodia analyzes the results of CSAM's pilot project in Takeo Province, including findings from local surveys about farming practices and the promotion of agricultural mechanization-based solutions to incentivize sustainably using straw residue as a resource. The pilot was implemented during 2021-2023 as part of a wider project titled 'Enabling Sustainable and Climate-smart Agriculture in Cambodia, Indonesia, and Nepal Through Mechanisation Solutions for Integrated Management of Straw Residue and Air Pollution Monitoring' with financial support from the China-ESCAP Cooperation Programme (CECP) and in partnership with Swisscontact and the Department of Agricultural Engineering of the Government of Cambodia.

III. CAMBODIA: AGRICULTURE AND AIR POLLUTION

The Kingdom of Cambodia, situated on the mainland of Southeast Asia, was chosen for CSAM's pilot project as it shares many characteristics with other regional mainland nations (i.e., Laos, Myanmar, Thailand, Viet Nam). Cambodia has the third highest fire count among countries in Southeast Asia, with around a quarter of these fires due to agricultural residue burning and around 62% of the fires due to slash and burn methods and timber harvesting[24,25]. Between 2 and 8 million tons of rice straw are subjected to burning yearly in Cambodia[9,26], producing high air pollutant concentrations with severe impacts on public health[7,26]. Furthermore, in January 2021, thousands of illegal burn sites were identified across Cambodia[27], indicating the urgent need for mechanization solutions and making Cambodia an ideal place to demonstrate what can be achieved across mainland Southeast Asia to reduce air pollution caused by biomass burning.

The CSAM pilot established its project site in the Takeo Province, where most of its nearly 116,000 residents are employed in rice production.

A. Study Area: Takéo Province, Cambodia

Takéo is one of 25 provinces in the Kingdom of Cambodia, comprised of nine districts and one municipality, 97 communes and 3 Sangkat, and 1,119 villages. The province is in the south of Cambodia and to the west of one of the country's largest rivers, Tonle Bassac. It borders the provinces of Kampot to the west, Kampong Speu to the northwest and Kandal to the north and east, and its southern boundary is the international boundary with Viet Nam (see Figure 4).

1.1.1 Map of the Country

Source: UN (2004)

Figure 4 Map of Cambodia and Takéo Province.

The province spans 3,563 km2, which is primarily low-laying plain land. It experiences a cool season from November to March (22-28°C), a hot season from March to May (28-36°C), and a rainy/monsoon season from May to October (24-32°C, with humidity up to 90%). The warm and humid climate, topography, and access to water make the province ideal for rice cultivation and growing a wide variety of crops.

The province is home to 6.4% of Cambodia's total population, with nearly one million residents (445,000 male and 479,758 female). The provincial capital city, Don Kaev, has only 39,000 residents, indicating a large majority of the population lives in rural areas. The main pillars of the economy are agricultural farming, fishery, rice, and fruit cropping. The many rural households of the province depend on agriculture for their livelihoods.

The Treang district of Takéo Province was selected as the site for the pilot project on integrated management of straw residue in Cambodia. This district has a total area of about 40,277 ha and a population of 115.808, of which most of the land and labour force is dedicated to rice production. There can be three cropping seasons annually for short varieties of paddy rice based on the irrigation system, indicating that this area is generating vast amounts of straw residue. The field trials were held at the Kbal Por Agricultural Engineering Center in Srangae commune, Treang district, Takeo province.

Most of the harvesting is done using combine harvesters. After the combine harvester harvests the rice, the rice straw residue is typically strewn in the field. Some farms in the district have ample labour; in these situations, they can collect the rice straw manually and use it in a circular model, predominantly as animal feed. However, many farms do not have enough labour and equipment to collect the straw and thus do not have time to plough the rice straw and allow it to decompose into natural fertilizer. In these instances, the farmers opt to openly burn the straw in the field to rapidly clear and prepare paddy land for the next planting season. This burning has adverse impacts on human health, the environment, and the economy. If rice straw could be efficiently collected and used sustainably instead of burnt, air pollution and its associated health impacts would be decreased, soil health could be improved, and new revenue streams for farmers could be created.

IV. CASE STUDY: IMPLEMENTATION OF MACHINERY IN TAKEO

An agreement for implementation of the pilot project in Cambodia was signed in 2021 between ESCAP and Swisscontact. The project was implemented in the field by the Department of Agricultural Engineering in Treang district, Takeo province, Cambodia, in three locations: Srangae, Sambour, and Thlok Communes, where the farmers mostly cultivate rice for three seasons per year and burn the rice straw after harvesting. The project aimed to deliver the following three outputs:

Output 1	Establish pilot site(s) in Cambodia for integrated management of straw residue informed by research on air pollution and GHG emissions from the agricultural sector.
Output 2	Test and adapt improved technologies and practices for integrated management of straw residue at pilot site(s).
Output 3	Enhance capacities of farming community and change agents for adopting improved technologies and practices for integrated management of straw residue.

The key project activities are summarised in the following sections.

A. Identifying the current farming status at the pilot sites

A baseline survey was developed to improve understanding about farmers' knowledge on rice straw collection, utilisation, storage, and management. The survey was conducted in Sambour, Srangae, and Thlok Communes; interviewing a total of 101 farmers (53% were women). A wealth of knowledge was gained from this exercise, providing strong motivation for the project implementation.

A key finding from the survey was that women play an important role in farming, participating in agricultural activities such as rice production, vegetable cultivation, and rice straw collection and management. Other key findings were that 1) the management and storage of rice straw is not standard practice across the households, and 2) most farmers burn the straw in the field (Figure 5). Reasons for the lack of rice straw management and burning in the field include insufficient time for straw collection and difficult field access. Moreover, most farmers no longer raise livestock, reducing the motivation for rice straw collection. Overall, it was found that most farmers lack understanding of the adverse effects of rice straw burning, and do not have sufficient knowledge of rice and vegetable cultivation techniques and rice straw collection, utilisation, storage, and management.

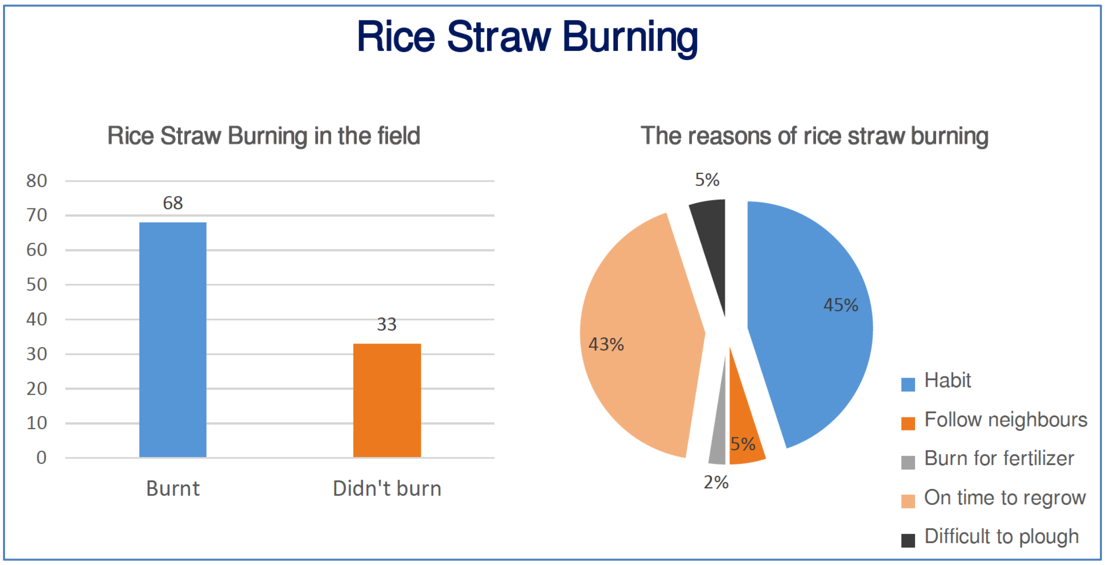

Figure 5. Baseline survey results for the questions regarding rice straw residue burning. Participants consisted of 101 farming households residing in the project area. Figure courtesy: Department of Agricultural Engineering, Cambodia.

B Inception workshop

An inception workshop with local stakeholders was held to jointly identify, review and discuss the location and action plan to implement the project effectively; creating a model that can be replicated in future target areas. The workshop involved representatives from Swisscontact – Cambodia, Department of Agricultural Engineering and other relevant departments of the General Directorate of Agriculture, provincial and district administration, local Commune councils, agricultural cooperatives, and agricultural machinery service providers.

During the workshop, participants were provided with current knowledge on straw management and equipment for straw collection and rice planting through presentations and participatory discussion. Two types of agricultural machinery equipment were selected for the implementation trials: the straw baler and the direct seed drill (Thai Kit Seed Drill), and plans were made for sessions to demonstrate the equipment under local conditions, to farmers and farming communities. To prioritize outreach to rural women, it was decided that one event dedicated to women participants would be included in the awareness and demonstration sessions.

C Field trials of agricultural equipment and adaptation

1. Straw Baler

The working group of the Department of Agricultural Engineering tested the straw baler at the field site in Treang district. During the trial, operation of the machinery was found to be strongly influenced by both the field size and equipment operators. The optimum operation was found to be under dry weather conditions, with no water present, and with dry straw. A skilled and experienced operator was found to generate greater efficiency. The efficiency of baler was measured to be 0.93 ha/h with a working speed of 2.94 km/h, collecting 88.93 pieces of straw/h. The remaining straw in the field was measured to be 5% of the total amount.

2. Direct Seed Drill

The working group of the Department of Agricultural Engineering also tested the planting equipment (direct seed drill) at the field site; collecting data on the performance of the machinery, the optimum conditions for operation, and the seed panting specifics. As in case of the straw baler, field size and skills of equipment operators were found to influence the performance of the seed drill, with more experienced operators achieving greater planting efficiency. The optimum operating conditions were again found to be under dry weather conditions, with well prepared and dry farmland. Adjustments to both the seed spacing and seed load were tested to suit the field area and technical requirements.

Based on the trials, certain adaptations were made to both the machinery. For instance, a component (sprocket) was replaced in the baler and technical adjustments made in the direct seed drill (changing of row length and seed rate) for more efficient performance of the machinery in the local conditions.

D. Awareness building and demonstration sessions

Four sessions were conducted for farmers and other relevant stakeholders to promote adoption of improved and integrated straw management technologies and practices, using the straw baler (two sessions with one particularly targeting women) and the direct seed drill (two sessions). The sessions, which reached out to 144 participants (46% women), addressed two aspects, firstly to transfer knowledge and secondly to demonstrate the use of the equipment in the field.

Figure 6: Demonstration of straw baler.

Figure 7: Demonstration of direct seed drill.

(Pictures courtesy: Department of Agricultural Engineering, Cambodia)

V. KEY RESULTS OF PILOT PROJECT IN CAMBODIA

The pilot project in Cambodia achieved the following key results at the targeted sites in relation to its objective to promote the sustainable and climate-smart management of straw residue through use of agricultural machinery-based solutions:

1. Enhanced awareness about the environmental impact of burning straw within the local farming communities and change agents.
2. Enhanced awareness about how machinery like the straw baler and direct seed drill enable integrated and climate-smart management of straw residue and bring economic and other benefits.
3. Dissemination of the results of the field trials of the machinery, including information on the efficiency of the machinery under local conditions.
4. Selected adaptations of the machinery to enhance performance in view of local needs.
5. Practical demonstration of the technical operation of the straw baler and direct seed drill in the field. Women farmers were especially engaged for promoting use of the machinery.

The results of a feedback questionnaire completed by the participants of the awareness and demonstration sessions also provided evidence of the uptake of the knowledge shared. For example:

- 98% of participants agreed or strongly agreed that the objective of engaging stakeholders to promote integrated management of straw residue through agricultural machinery was achieved.
- 100% agreed or strongly agreed that their capacity to implement improved technologies and practices for integrated management of straw residue was enhanced.
- 97% agreed or strongly agreed that gender dimensions were considered (e.g., how the project activities can benefit women).

In terms of wider uptake of the results, the Department of Agricultural Engineering of Cambodia has agreed to include the project activities in other provinces subject to budget availability.

VI. POLICY RECOMMENDATIONS

A. Strengthen measures to monitor air quality and agricultural burning

There is need to improve monitoring of air pollutants and agricultural burning hotspots in order to measure air pollution exposure and to identify the key polluting sources. Advanced monitoring using satellite and ground-based measurements together with state-of-the-art computer modelling can be utilised to identify the most severe agricultural burning hotspots[31] and investments in sustainable agricultural mechanization programmes can be prioritized accordingly.

B. Support testing and demonstration of machinery in the field

Testing of agricultural equipment and demonstration to farming communities in a local context is of the utmost importance. Monitoring the performance of the equipment in the field will enable assessment of the compatibility between the machinery and the local agro-ecological conditions, and can ensure that information on machinery operation accuracy, efficiency, workload, and other variations in the field from local usage can be gathered and disseminated.

Moreover, necessary technical and/or procedural adaptations can be identified and implemented to improve equipment efficiency under local conditions.

C. Promote conservation agriculture

Sustainable management of crop residue is an important element of conservation agriculture which includes maintenance of permanent soil cover and minimum soil disturbance as two of its three core principles. Cambodia has been taking important strides forward in promoting conservation agriculture and the Cambodian Conservation Agriculture and Sustainable Intensification Consortium (CASIC) has been established in recent years to enable multi-stakeholder coordination. Ongoing efforts and policy support in this direction should be continued and further reinforced as part of a strategy to increase the resilience of agriculture as well as reduce GHG emissions from the sector.

D. Ensure gender mainstreaming

Women play an important role in farming and uptake of new technologies and their role is becoming more prominent in the backdrop of rural to urban migration of men for jobs. There is strong need to increase access of women farmers and agricultural workers to resources such as agricultural machinery and equipment, including for sustainable management of crop residues, and they should be included in all aspects of engagement and training.

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