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Agricultural Technological Practices and Gaps for Climate Change Adaptation

Sam Sreymom with Ouch Chhuong

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Acronyms

CARDI	Cambodian Agricultural Research and Development Institute
CEDAC	Centre d'Etude et de Developpement Agricole Cambodgien
CSA	Climate smart agriculture
DAO	District Agricultural Office
DRC	Department of Rice Crop
EMV	Early maturity variety
FGD	Focus group discussion
FWUC	Farmer Water User Community
HARVEST	Helping Address Rural Vulnerabilities and Ecosystem Stability
KII	Key Informant Interview
LMV	Late maturity variety
MAFF	Ministry of Agriculture, Forestry and Fisheries
MMV	Medium maturity variety
NGO	Non-government organisation
PADEE	Project for Agriculture Development and Economic Empowerment
PDA	Provincial Department of Agriculture
R&D	Research and development
SMS	Subject matter specialist
SRI	System of Rice Intensification

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Executive summary

Agriculture plays an important role in sustaining rural livelihoods. Eighty-three percent of rural people are engaged in agriculture (NIS and MAFF 2014). An emerging problem facing agriculture is climate change. The anticipated impacts of climate change and variability on agriculture include changes in rainfall patterns, higher temperatures, increased frequency and intensity of flood and drought, and increased incidence of pests and disease (MOE and UNDP 2011). These serious problems emphasise the critical need for climate-smart agriculture (CSA) (FAO 2013). Among CSA techniques, the system of rice intensification (SRI) is already being practised in Cambodia. SRI is a set of best practices that can increase rice yield on infertile soil to as much as 15 tonnes per ha, reduce the amount of irrigation water required, and use only local inputs (Willem 2002; Norman 2007; Kassam, Stoop and Uphoff 2011).

This study identifies local knowledge and SRI practices in the Tonle Sap and Mekong delta agro-ecological zones. It looks at gaps in local practices and suggests ways of closing those gaps to enable farmers to cope with the effects of climate change. Primary data was collected from key informant interviews, focus group discussions and in-depth interviews with various institutions and individuals concerned.

The selection of improved varieties is the most common SRI practice adopted to date. Market-driven varieties are the most popular. Other SRI practices have been partly adopted and adapted to local conditions. Local people choose only the practices they think beneficial and feasible for them. The study also identifies various factors affecting this selection: socioeconomic, agronomic, physical, technological and institutional.

Local communities need to mobilise local resources. Collective action is therefore required to share technical information, foster local innovation in dealing with weeds and adapting new practices, improve access to markets and inputs, identify local water storage options and share risks and labour.

NGOs should collaborate more closely with departments involved with climate change adaptation and SRI to expand coverage of CSA. They should also focus more on local innovations and consider the complexity and technical requirements of each practice.

NGOs and government extension agents should provide advice and services to help farmers connect to local and distant markets. Specialist departments and institutions also have to be engaged in research and development. The government should not only increase the number of village agents but also mobilise local people to work as local extension workers.

1. Introduction

Agriculture plays an important role in sustaining rural livelihoods. Eighty-three percent of rural people are engaged in agriculture (NIS and MAFF 2013). It contributed 31.6 percent of gross domestic product in 2013. An emerging problem for agriculture is climate change, which has become an issue attracting a lot of attention from government, development partners and non-government organisations. Climate prediction models rank Cambodia as one of the most vulnerable South-East Asian countries (Yusurf et al. 2009). Under climate change scenarios of a hotter and wetter climate in 2050, Cambodian yields can be increased if it adopts some technologies (Spatial Dev and IFPRI 2014). Enhanced nitrogen-use efficiency could increase rice yields up to 10.6 percent. Also, protection from weeds would increase yields up to 9.9 percent. (Spatial Dev and IFPRI 2014).The anticipated impacts of climate change and variability on agriculture include changes in rainfall patterns, higher temperatures, increased frequency and intensity of flood and drought and increased incidence of pest and disease (MOE and UNDP 2011). Predicted changes include the onset of rainfall and rainfall distribution between areas; wet seasons would be shorter and more intensive and dry seasons longer and hotter. Higher temperatures would reduce grain yield. Flood and drought would be more intense and frequent. The onset of seasons will be less predictable. Pests and disease are expected to increase, threatening agricultural production (MOE and UNDP 2011).

To confront these problems, climate-smart agriculture (CSA) was introduced to increase agricultural productivity, enhance local community resilience and reduce GHG emissions where possible (FAO 2013). CSA comprises many technologies and practices: sustainable land management, landscape management, system of rice intensification (SRI), conservation agriculture and soil-water conservation. Among these, SRI has already been active in Cambodia. SRI is a set of good practices originally developed in Madagascar in the 1980s and 1990s by French Jesuit Father Henri de Laulaniéto to increase the rice yield of infertile soil up to 15tonnes/ha with less irrigation water and only local inputs (Stoop 2002; Uphoff 2007; Kassam, Stoop and Uphoff 2011). De Laulaniéto in the 1990s continued to work with farmers by setting up the Association of TeySain, meaning "to improve the mind" (Kassam, Stoop and Uphoff 2011). SRI is not a technology but a set of practices to help farmers "produce more output with less input" of soil, water, labour and capital (Uphoff 2007). SRI has been spread by NGOs to many countries. By 2011, 5 million farmers in 50 countries had adopted or were testing SRI (Kassam, Stoop and Uphoff2011).

How will SRI deal with climate change? SRI needs less water demand compared to traditional and conventional practices and with this reduced water demand, it can deal with drought and rainfall variability (Uphoff 2007; World Bank Institute 2008; and Oxfam America and WWF-ICRISAT Project 2010). Uphoff (2005) claims that SRI practices develop "large and healthy root systems" that are strong enough to cope with water stress, drought, storm, wind and rainfall variability. He also mentions that the practices can help plants to resist pests and disease. Original SRI practices consist only of transplanting methods, and direct seeding is excluded. The practices are to be conducted in irrigated, not rain-fed, systems. The original SRI principles and practices include:

- Young seedlings: age of seedlings is just 8-12 days, and if careful planting is performed, "much greater tilling" is expected.

- Single seedlings: planting just one seedling per hill with wide space allows “much greater root development”.
- Spacing: wide rather than dense, to enhance root development. A row pattern of planting is replaced by a “square pattern” (25x25cm). However, local conditions determine the spacing, and farmers can experiment. SRI also reduces seeding rate.
- Moist field: during vegetative period, field is “slightly irrigated”, not flooded or saturated as usual. This requires intermittent water supply. Also, SRI requires fields to “dry out” to enhance root aeration.
- Weeding: weeds become a major problem without flooding. Several weedings are required. Weeding helps to aerate the soil, for “greater root and canopy growth”.
- Compost: Since SRI practices were developed with poor soil, composting is recommended, which is a local input that people do not need to pay for (Uphoff 2000).

SRI is flexible, based on local conditions, and farmers can always experiment with any practices to fit their circumstances (Uphoff 2007). SRI was introduced into Cambodia by Centre d’Etude et de Developpement Agricole Cambodgien (CEDAC) in 2000 combining SRI principles of water and plant management with SRI (Yang 2002). Since then, other NGOs and government have shifted their focus to SRI. An SRI secretariat was established in January 2005 under the Department of Agronomy and Agricultural Land Improvement, later changed to the General Directorate of Agriculture (Ngin 2010). SRI has been promoted in different parts of Cambodia by 47 NGOs and development projects (Ngin 2010). The practices and principles of SRI keep evolving to be local and to cope with climate change issues. However, the core principles and practices remain the same while being extended from irrigated to rain-fed fields. Moreover, the planting method is not limited to transplanting, but now includes direct seeding and broadcasting. CEDAC promotes 12 SRI principles:

- Level the soil of the seedbed and rice field.
- Apply natural fertiliser (especially compost).
- Weed frequently to improve soil aeration (two to four times).
- Wider spacing between hills.
- Transplant seedlings quickly and carefully.
- Transplant seedlings in a square pattern.
- Maintain a lower level of water in the rice field.
- Transplant fewer seedlings per hill; preferably one seedling (maximum of three).
- Transplant young seedlings, ideally less than 15 days old.
- Shallow transplanting.
- When transplanting, softly uproot seedlings to avoid trauma, especially to the roots.
- Transplant only healthy seedlings. (Burnette 2009)

However, CEDAC is now also working on direct seeding and identifying appropriate amount of seed for the seeding (Yang 2011). The manuals of both the Department of Rice Crops (DRCs) of Ministry of Agriculture, Forestry and Fisheries (MAFF) and Cambodian Agricultural Research and Development Institute (CARDI) focus on the upgraded SRI principles and practices. The upgrade takes into account the labour shortage for transplanting and the majority of rain-fed systems in Cambodia. CARDI does not use the term SRI but rather TPIRP: Technology

Package for Increasing Rice Productivity or just CARDI's Technical Package, while the DRC uses TPSRI: Technical Package for System of Rice Intensification; however, they are nearly identical. Direct seeding can also adapt to climate variability and change since it reduces the water required for nursery fields (Pathak et al. 2011). Compared to transplanning, it can save up to 32 percent of water (Pathak et al. 2011).

In 2010, around 130,000 farmers were employing the original SRI (transplanting) methods and concepts (Yang 2011). However, there is little information on how SRI transplanting is being practised and adapted to local conditions (Ly et al. 2012). Also limited is information regarding upgraded SRI.

2. Research objectives and questions

This study identifies local knowledge and technological practices regarding SRI, as well as gaps in these practices and how to fill those gaps to cope with climate change. It is based in the Tonle Sap and Mekong delta agro-ecological zones.

In particular, the study aims to answer the questions:

1. What are the current practices of SRI?

2. What are factors affecting adoption of SRI?

3. Research methods

Primary data collection employed key informant interviews (KII), focus group discussion (FGD) and in-depth interviews (II). Secondary collection involved data or information from reports and other documents. IIs were conducted with informants from concerned institutions including provincial departments of agriculture (PDAs), district agricultural offices (DAOs), MAFF, CARDI and climate-related projects including HARVEST,[1] PADEE,[2] CEDAC[3] and CCCA.[4] FGDs were administered with a group including commune chiefs, commune councillors responsible for agriculture within the commune, and/or the head or members of farmer water user associations (FWUC).

1 Helping Address Rural Vulnerabilities and Ecosystem Stability is funded by United States Feed the Future and Global Climate Change initiatives.

2 Project for Agriculture Development and Economic Empowerment is funded from IFAD to focus on improving poor people's livelihoods by providing agricultural technologies and establishing local savings.

3 CEDAC is an NGO working on SRI and MPF. It has many projects on both SRI and MPF.

4 Cambodia Climate Change Alliance provides grants to many local NGOs to work on climate change adaptation.

Table 1: Study sites

Agro-ecological zone	FGD				KII		
	Commune	District	Water Sources	Participant	Institution	Informant	Interviewee
Tonle Sap	Kompong Chhnang						
	Thlok Vien (TV)	Samaki Meanchey	Rain	Commune chief and councils	FWUC of Tang Krasang (TKS) commune of Teuk Phos district[5]	Chief of FWUC	Commune chief
					CEDAC[6]		Member of FWUC (TKS)
					PDA	Head of department	
	Kompong Thom						
	Sala Visai (SV)	Prasat Ballangk	Rain		PDA	Head of extension office	Commune councillor
	Ou Kanthor (OK)	Stung Saen	Rain and irrigation		HARVEST	Officer specialising in rice	Head of FWUC
					HARVEST	Officer specialising in vegetables	
Lower Mekong	Prey Veng						
	Chong Ampil (CA)	Kanh chriech	Rain and irrigation		PDA	Head of department	Commune councillor
	Theay (TH)	Ba Phnom	Rain and irrigated		WOMAN[7]	Officers	Commune chief
	Takeo						
	Krapum Chhuk (KPC)	Koh Andaet	Rain and irrigation		DAO	Head of district office	Head of FWUC
	Trapeang Thom Khang Cheung (TTKC)	Tram Kak	Rain and irrigation		DAO	Head of district office	Commune chief
Phnom Penh	Climate-related institution						
					MAFF Department of Agricultural Extension	Head of Human Resource Development Office	
					CARDI	Head of Agronomy and Farming System Office	
					PADEE	National Project Manager	

5 Tang Krasang commune was intended for an FGD, but the targeted people were not available, so the FWUC chief was interviewed instead.
6 The research team did not meet a CEDAC official during this study; the information is drawn from a KII done in 2013 for another climate-related project.
7 WOMAN is a local organisation funded by CCCA working on agricultural extension services.

Data gathered during KIIs covered general conditions of agricultural production in the province, climate-related projects, agricultural extension services, challenges and needs for improving the production and adapting to climate variability and change. FGDs reveal local conditions, challenges and needs. They also provide detailed information on each step of rice production. IIs were used to dig into specific details of each step of cultivation in each commune. Besides this primary data, which was generally qualitative, secondary data consisted of quantitative data on rice production in Cambodia and targeted provinces and qualitative data on SRI practices from various institutions.

Procedures for selecting communes for FGDs and informants for KII and in-depth interviews were:

- First, to select agro-ecological zones among the four; two were selected because they are the largest rice producing zones.
- Second, choosing four communes (two in each province) in the two targeted zones that are the target of climate-related agricultural projects or vulnerable to flood and drought. Both rain-fed and irrigated communes in the wet season were the focus to look into SRI practices. Informants were selected based on their connection with climate-related activities.

Detailed information on communes and informants chosen for the study is contained in Table 1. In total, 13 KIIs, seven FGDs and eight IIs were conducted from May to July 2014. For IIs, one member of each FGD was selected; in Tang Krasang, a member of the FWUC was approached.

4. Literature review and analytical framework

4.1. Rice ecosystems

Rice ecosystems in Cambodia are divided into four categories: upland, rain-fed lowland, deep water and irrigated (Nestbitt 1997). The Tonle Sap and lower Mekong zones have rain-fed, deep water and irrigated ecosystems. In rain-fed lowland, rice fields are distinguished as: upper, middle lower based on topography (Nesbitt 1997; Wang 2012). However, an additional field is included in rice ecosystems called early wet season (EWS) based on DRCs (2013). EWS is either a middle or lower field and is cultivated with water from a canal or pond or with groundwater (DRCs 2013). Upper fields are completely rainfed, while middle and lower are both rainfed and irrigated (Wang 2012). In some areas, only upper and lower fields exist (Nesbitt 1997). For deep water ecosystems, two types of fields are identified: those flooded with 50-100cm of water for at least one month and those with more than 100cm for at least one month. There are three types of irrigated ecosystem: fully irrigated, receding and pre-rising.

4.2. SRI in Cambodia

In 2005, the MAFF endorsed and promoted SRI. The National Strategic Development Plans 2006-10 and 2009-13 included SRI aiming at increasing rice productivity.[8] Below are the most recent suggested practices, published in 2013 by DRCs and 2011 by CARDI.

8 As of 26 September 2014, SRI international Network and Resources Center listed on its website: http://sri.ciifad.cornell.edu/countries/cambodia/.

4.2.1. Variety selection

Varieties are selected based on time to maturity and height appropriate to the local weather, climate, soil and water. In flood-prone areas, varieties that can be submerged are selected. Farmers should also choose varieties that have market value, are resistant to pests and have high yields. The MAFF has released 38 rice varieties, each suitable for specific conditions.

Many varieties are used in the study areas. According to Wang (2012), the three rice varieties in Cambodia are modern, traditional, and improved traditional varieties. In 2011, the Royal Government of Cambodia has recommended 10 varieties[9] among the 38 released varieties to increase rice production and promote rice exports (Ouk 2011). Among the 38, some are resistant to or tolerant of biotic and abiotic stresses including flood, drought, Brown Plant Hopper (BHP) heat, pest and striped stem borer (Ouk 2011). Excluded the striped stem borer, the others are climate related (Ouk 2011). As shown in Table 2, tolerance of stresses is still limited, but there is ongoing R&D conducted by CARDI. Based on time to maturity, rice varieties are divided into Early Maturity Variety (EMV), Medium Maturity Variety (MMV) and Late Maturity Variety (LMV).

Table 2: Rice varieties and climate-related stresses

Stresses	Flood/waterlogging	Drought	BPH**	Heat	Pest
Varieties	10-12 days of submergence: CAR9, Phka Romduol,* Phka Romdeng*	Moderate drought: CAR3, CAR4*	IR Kesar, Kru, Chul'sa*, CAR12	Under development	Striped stem borer: Kru, IR72, Sen Pidor*, IR66*
	7-10 days of submergence: CAR6*, Phka Romchek, Phka Romeat*				Rats, golden snails and others: IPM Weeds: IPM

Source: Ouk 2011

* 10 recommended varieties

4.2.2. Seed preparation

The germination rate of seeds must be over 85 percent. Farmers can identify the rate using the following procedure. Randomly select seeds from each rice sack from upper, middle and lower parts; then randomly pick 100 seeds from this selection. Farmers should do this for three or four samples. Then the sample is soaked in three centimetres of water and stirred well. After three days, count the sprouted seeds; the number of sprouts is the germination rate. This allow farmers to know how much seed to plant.

Preparation for transplanting rice has a specific procedure. The farmer first has to know the germination rate and then select only fully germinated seeds to sow. To make sure that the selected seed is fully germinated, before sowing, the farmer has to germinate the selected seed by keep it in a rag and soaking it for 24 hours, then lifting the rag from water and incubating the seed for another 24 hours with rice husk over it to increase the temperature. During the incubation period, it has to be moistened and turned upside down every 12 hours.

There are also specific steps for preparing a nursery. There are two types of bed: dry nursery and dapog. The dry bed is raised and harrowed, and compost is applied. One hundred grams of seed are used per square metre of the nursery. Fifteen to 20kg of good and genetically pure

9 The 10 varieties include 3 EMVs (Sen Pidor, Chul'sa, IR66), 4 MMVs (Phka Romduol, Phka Romeat, Phka Romdeng, Phka Chan SenSar), and 3 LMVs (Raing Chey, VAR4, CAR6) based on Ouk 2011.

seed are transplanted over one hectare. Dapog is used when the farmer finds it hard to establish a sowing bed and needs seedlings in a short time. It is a bit more complicated than the dry bed. It needs banana leaves or a plastic sheet underneath and uses soil mixed with compost and rice husk ashes. There are both advantages and disadvantages of both beds, so it depends on locality.

4.2.3. Field preparation

Ploughing is very effective at aerating soil, killing pests and weeds. It is recommended that ploughing be done twice for normal and thrice for weedy fields. For transplanting, the field is ploughed twice and harrowed once. Leveling should be carried out simultaneously. In an uneven field, small levees are established to for water management and feriliser application. These help reduce weeds and allows the seedlings to root easily. Also, a specific depth of ploughing depends on soil type.

4.2.4. Seedlings

Age of seedlings for transplanting depends on vegetative stage of rice. Seedlings less than 15days old should be used for photoperiod-insensitive EMVs, less than20 days old for photoperiod-sensitive MMVs and less than 30 days old for LMVs. There are frequent climate-related problems, particularly with water shortages causing seedlings to age before they can be transplanted. Usually, the farmer begins nursery preparation and waits for the soil to be ready (soft and muddy enough) for transplanting. However, with the current climate situation, it is suggested the farmer change the practice, preparing the soil first and then wait for the seedlings.

4.2.5. Planting methods

Two planting methods of SRI are recommended: broadcasting/direct seeding and transplanting. Broadcasting saves labour and time but risks weeds, pests and disease. Broadcasting also has to be done on a level field to ensure a high yield, and it consumes many more seeds compared than transplanting.

There are three ways of broadcasting. The first is to cast dry seeds on dry soil and wait for rain or pump water from a canal. The second is broadcasting germinated seeds (soaked for12hours and incubated for 24 hour) on muddy soil. The third is broadcasting wet seeds on flooded soil. In this case, the soil is prepared before flood; the seed is broadcast when the water recedes and water standing in the field at 20-30cm deep. The rate of seeding is very high, usually 150-250kg/ha, but with the help of a drum seeder, it is reduced to only 80-100kg/ha for irrigated areas and 100-120kg/ha for rain-fed areas. For rainfed broadcasting, if rainfall is late, the farmer could harrow again after broadcasting to make sure weeds are not grown and lost to birds. If a drum seeder is not available, the farmer should use only 100-150kg/ha with skilful and even broadcasting.

Technically, transplanting should focus on amount, space, shape and depth. One or two young and healthy seedlings per hill are recommended if the fields are ready for transplanting. Since drought is always a major problem for rainfed lowland and delays transplanting, three to five older seedlings per hill are suggested. If the seedlings are more than 1.5 months old because of prolonged drought, photoperiod-sensitive EMVs should be resown in nursery beds. Infertile soil, a space of 20cm between seedlings and in infertile soil 25cm is reported to give best results since the seedlings do not have to compete for light and water. SRI considers a square transplanting pattern ideal. The depth of seedlings should be shallow, up to 2 cm without folding the root. But, if it is sandy soil and drought occurs, shallow transplanting will cause damage to the seedlings. Hence, transplanting depth depend on types of soil and frequency of climate-related events.

4.2.6. Soil fertility management

Each soil type requires different ways of soil fertility management. Rice production requires many nutrients from the soil, and they should be returned to the soil to sustain production. Although 11 soil types require different types and quantity for nutrients, they require nearly the same integrated fertility management. Two types of fertilisers are suggested: natural and chemical.

Compost, green manure, animal dung and biogas waste are natural fertilisers which farmers can manage on their own without any expense. Three to 10 tonnes of compost can be applied as basal to field. To prevent nutrient loss, applied compost should be harrowed. During the vegetative stage, well-decayed compost can be applied. Green manure such as Chromolaena odorata (tuntrean khet) should be grown and used underneath and as topdressing. Soybeans are not only good for enriching soil, but also for profit when grown in the early dry season using moisture left in the soil. Farmers should also plough rice stubble into the soil immediately after harvesting rather than burn it, since it is a good source of soil nutrients.

If natural fertiliser is not available or sufficient, chemical fertilisers can replace it. Three types of fertilsers are commonly used in Cambodia: nitrogen (N), phosphate (P_2O_5) and potash (K_2O). Technically, they should be applied as of the following. Application of fertiliser containing P_2O_5 is required as basal during tilling and panicle formation. The amount should comply with CARDI's recommendations. Local experiment is also encouraged.

4.2.7. Water management

Each rice variety has its own water demand. Varieties of upland rice need less water than low land varieties. Irrigation and strong field bunds are needed for the lowland. For transplanting rice, water depth of 1-5cm should be maintained. During the vegetative phase, particularly tilling, standing water should be at 2.5cm. Water should be drained from field and kept for two to three days in case drought is not expected. At the end of the wet season, a lack of water usually occurs, so ensuring water standing in the field until the end of the period is a must. It seems that these practices are for irrigated areas only; for rain-fed areas, to deal with drought over a short period, a 20m x 10m pond is suggested.

4.2.8. Weed, pest and disease management

Many weed control ways are available. Ploughing should be done on a moist field and should be followed by harrowing to ensure evenness. Two weedings by hand or with tools are suggested: 15 days after transplanting and another 15 days after that but it depends on weed growth condition. If these practices are not effective, herbicides should be used.

There are also many non-toxic means for both pest management and treating rice disease, but if they persist, pesticide and fungicide are recommended.

4.3. Factors affecting adoption

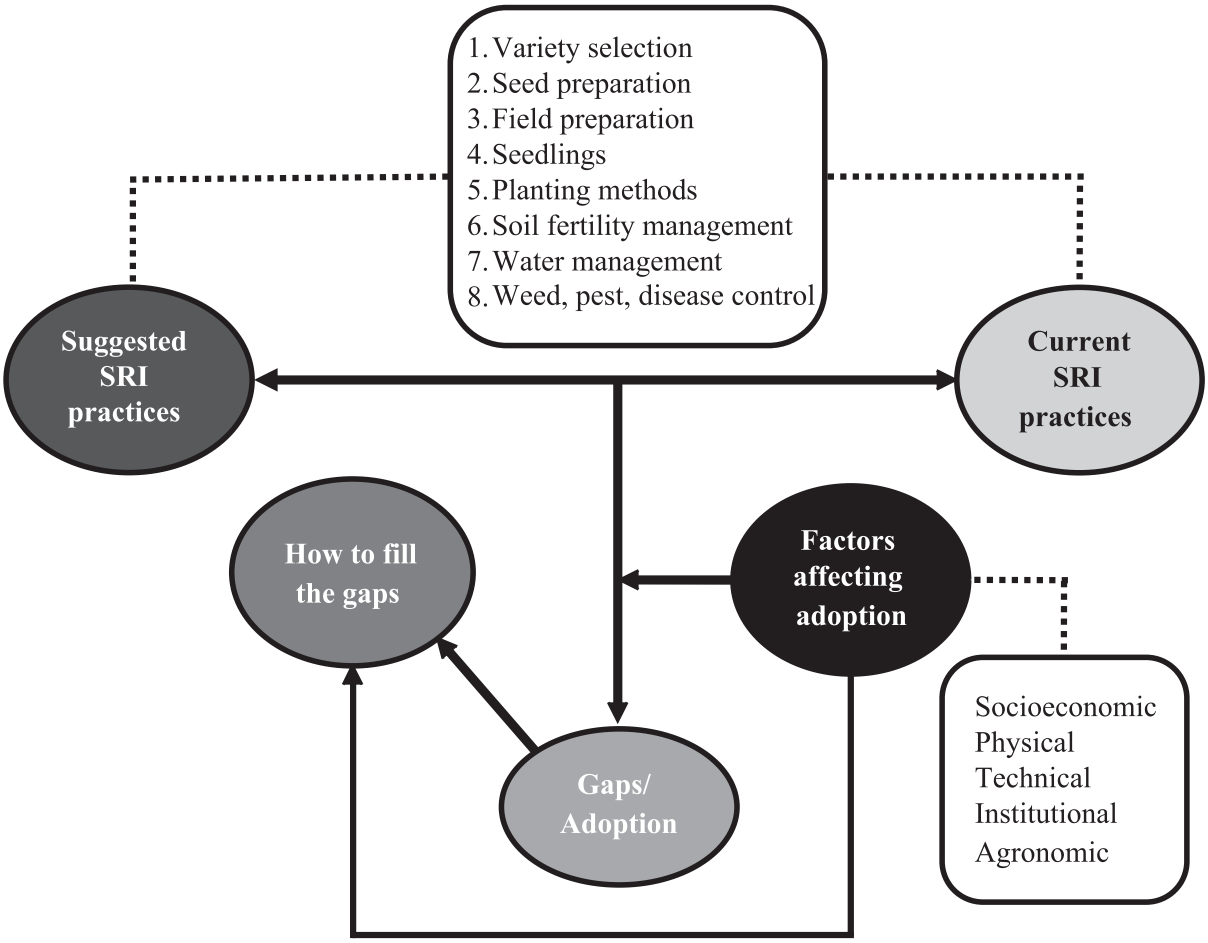
Although both SRI and MPF have been promoted for a long time, farmers adopting them are still few relative to the efforts of government and NGOs. Several causes discourage farmers from adopting these practices even when they have proved to be effective in enhancing livelihoods. Because SRI concentrates on transplanting, the intensive labour required is a factor affecting farmers' adoption according to many studies (FAO 2012; Ly et al. 2012; Barrett et al. 2004; Latif et al. 2005; Moser and Barrett 2003; Tsujimoto et al. 2009). Besides socio-economic factors, a physical constraint on adopting SRI is water problems due to topographical conditions, drainage, irrigation infrastructure, availability and irregular rainfall and flash floods (Katambara et al. 2013; Feuer 2008; Ly et al. 2012; Beadman 2009; Rappocciolo 2012). Water storage is another constraint since SRI requires water control (Laksana et al. 2013; Yang 2011). Limited access to inputs including seeds, organic and inorganic fertilisers and agricultural machineries is also observed to limit farmers' adoption of SRI (McCarthy et al. 2011; Beadman 2009; Ly et al. 2012; Yang 2011; Feuer 2008; Rappocciolo 2012). Limited access to markets discourages people from adopting climate-smart agriculture as a whole and makes people consider only subsistence farming (FAO 2012; McCarthy 2011; Lamboll and Nelson 2012). Farmers are reported to have no or limited access to technical information and proper extension services, and that is a barrier to their adopting the practices confidently (Lamboll and Nelson 2012; FAO 2012). Risking to a lot of weeding is reported if people apply the broadcast method (Farooq et al. 2011; Pathak et al. 2011).

Factors that increase adoption are also found in many studies. Increased yield motivates farmers to take up the practices (Mao, Tongdeelert and Chumjai 2008; Beadman 2009: Tsurui, Yamaji and Suk 2010). Less input, including seeds and inorganic fertiliser, encourages farmers as well (Tsurui, Yamaji and Suk 2010; Namara, Weligamage and Barker 2003). The discouraging role of intensive labour has been mentioned above. But studies by Uphoff (2007), Satyanaraya, Thiyagarajan and Uphoff (2007) and Tsurui, Yamaji and Suk (2010), claim that SRI reduces labour. Farmers are reported to adopt SRI transplanting practices because they save labour on uprooting and transplanting a lot of seedlings (Tsurui, Yamaji and Suk 2010). But indirect seeding, SRI helps reduce labour compared to conventional practices and labour in transplanting (Ly et al. 2012; Pathak et al. 2011). Some other studies also support the conclusion that direct seeding reduces labour (Farooq et al. 2011). Likewise, direct seeding reduces water demand, and that is why people start to focus on this practice (Farooq et al. 2011; Pathak et al. 2011). Dealing with climate change, particularly drought, is another value of direct seeding that farmers consider (Pathak et al. 2011; Haefele et al. 2010). Access to technical information is also a factor among all affecting uptake of the agricultural practices (Lamboll and Nelson 2012). A study in Sri Lanka found that this factor increases farmers' adoption of SRI practices, and the more farmers attend training, the greater the likelihood that they will adopt the practices (Namara, Weligamage and Barker. 2003).

4.4. Analytical framework

A literature review of CSA-related practices, specifically SRI, provides a clear basis for identifying the gaps between ideal and real practices in Cambodia, particularly in the Tonle Sap and lower Mekong agro-ecological zones. These zones receive a lot of attention from both government and NGOs. Rather than digging out the practice gaps, this study will find ways to fill those gaps by considering the barriers and motivations.

Figure 1: Analytical framework



5. Rice production of studied communes

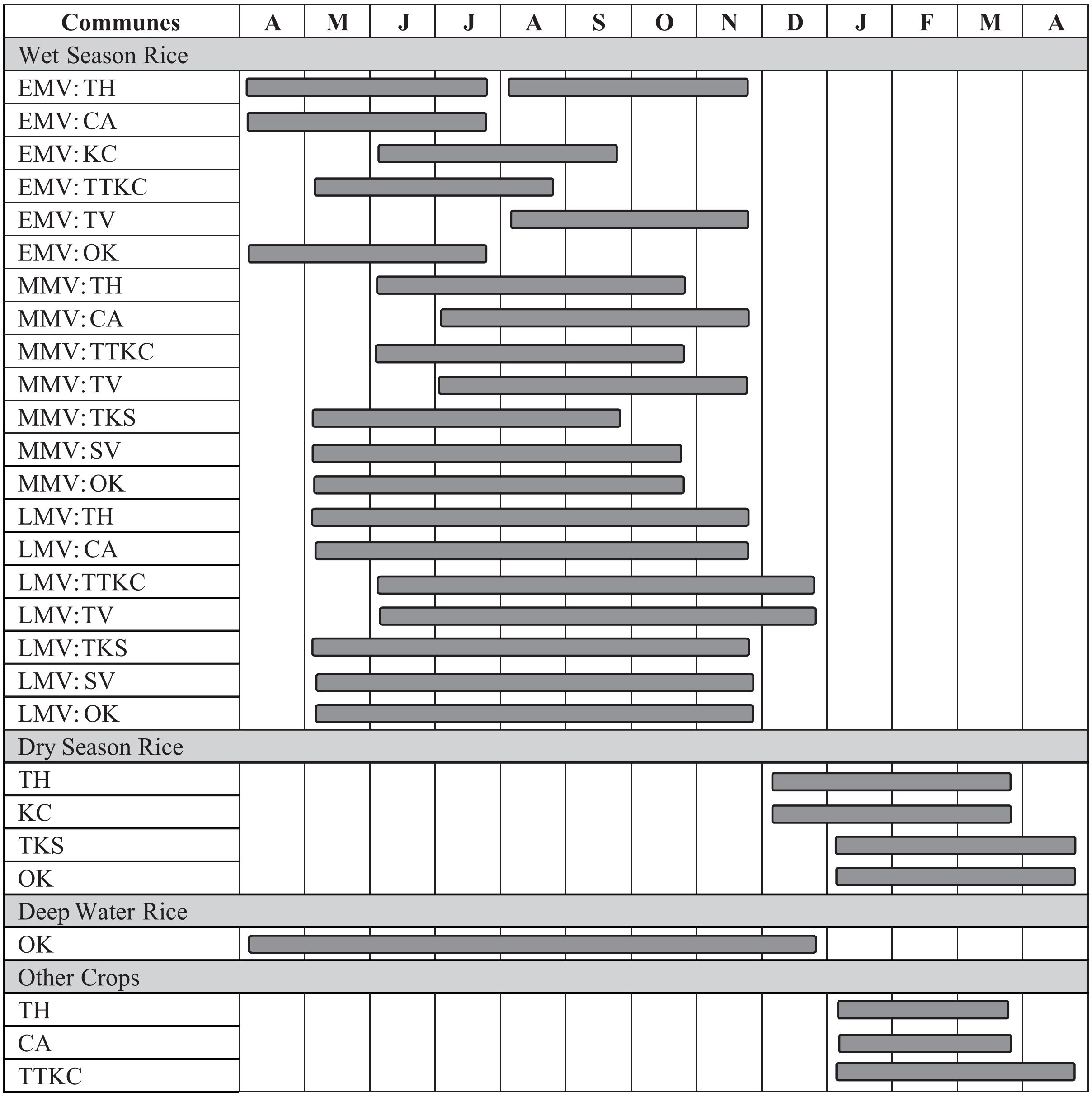
The main livelihood of the eight visited communes is rice farming. Around 98 percent of people living in those communes depend on agriculture as their main job (NCDD 2010).Wet season rice was cultivated in all communes, while dry season rice was planted in only four.

There are four types of wet season cultivation in the visited communes: There are four types of wet season cultivation the visited communes: EWS[10], and Middle Wet Season (MWS) which includes EMV, MMV, and LMV.EWS is becoming more popular since it helps to double or triple crops per year due to its compatibility with early maturity varieties such as IR504, IR85 and IR66. The government also promotes this practice since it contributes to coping with changes in rainfall patterns and the small drought in the wet season, which usually happens in July and August. EWS cultivation using usually starts in April/May and ends in July/August while EMV of MWS is cultivated in July/August and harvested in September/November. MWS cultivation using MMV and LMV starts in May/June and ends in December (Figure 2). DS cultivation, which usually uses EMV, begins in December/January and is harvested in March/

10 EWS cultivation also use EMV.

April. Cash crops are also planted in three communes. The rain-fed system is dominant among the visited communes for wet season cultivation (Figure 3).

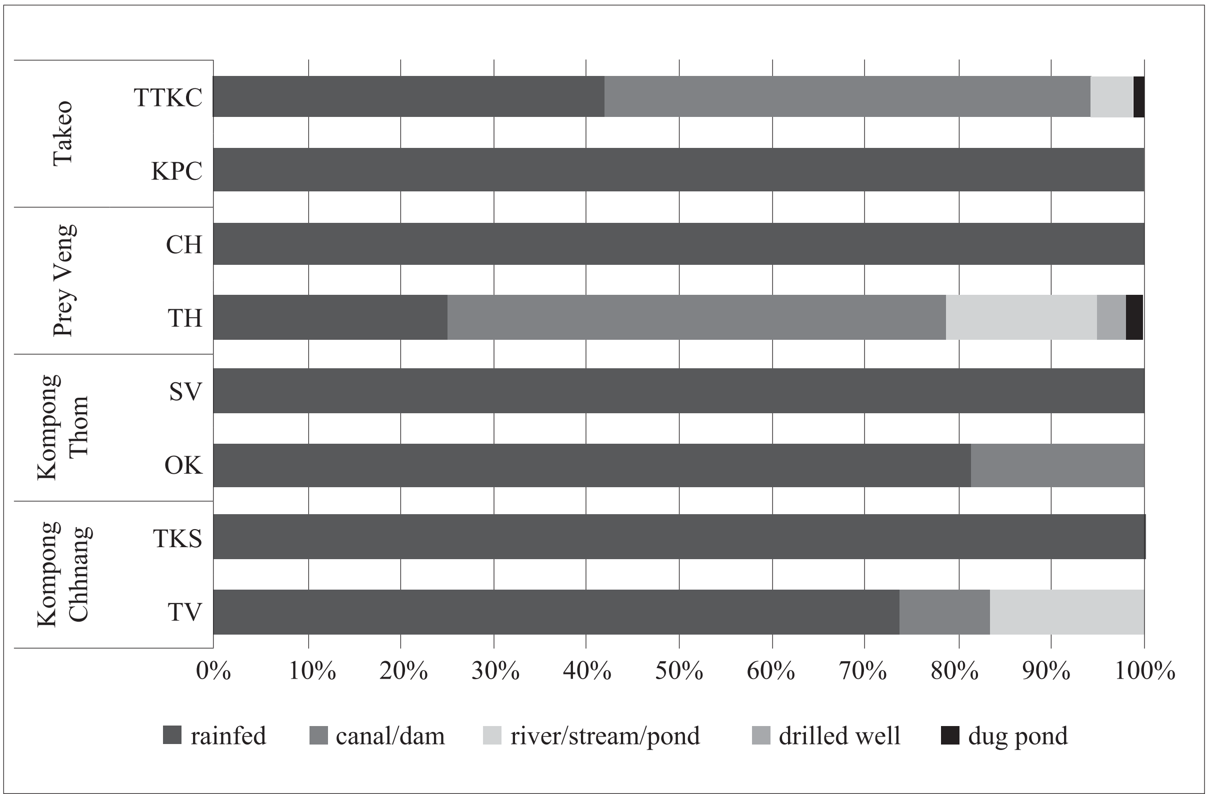
Figure 2: Crop calendar in the visited communes



Source: Discussions and interviews 2014

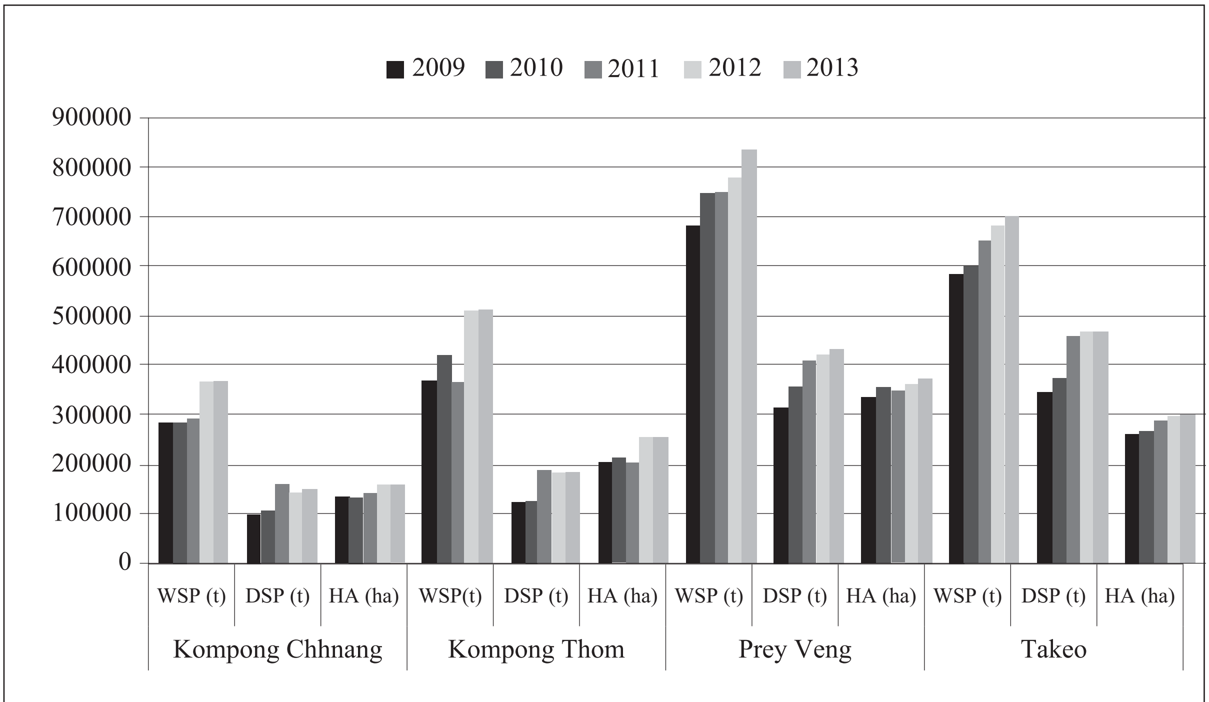
Based on MAFF reports, rice production in both wet and dry seasons is increasing regardless of province. Wet season production in the two provinces of lower Mekong zone is greater than that of the Tonle Sap zone (Figure 4). The average agricultural land holding of farmers was 1.250 for Kompong Chhnang, 1.754 for Kompong Thom, 1.161 for Prey Veng, and 0.913 hectare for Takeo (NIS and MAFF 2014). However, many farmers own less than 1ha of rice land; 68 percent of farmers in Theay commune of Prey Veng fall into this category.

Figure 3: Water sources in wet season 2010



Source: NCDD 2010

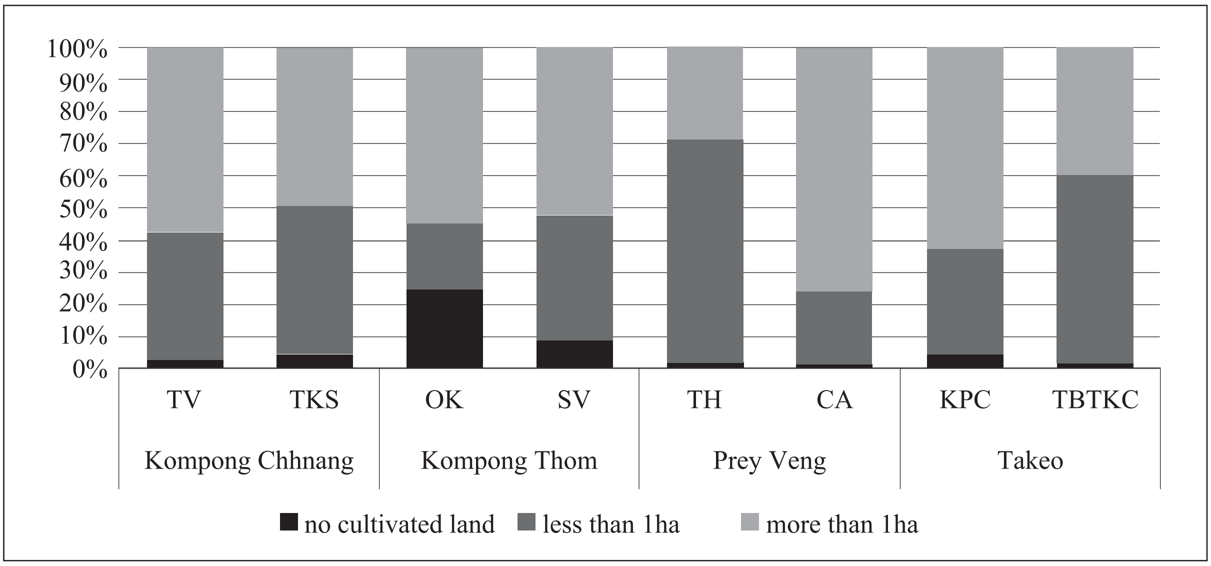
Figure 4: Rice production and harvested area, 2009-2013



Source: MAFF 2013

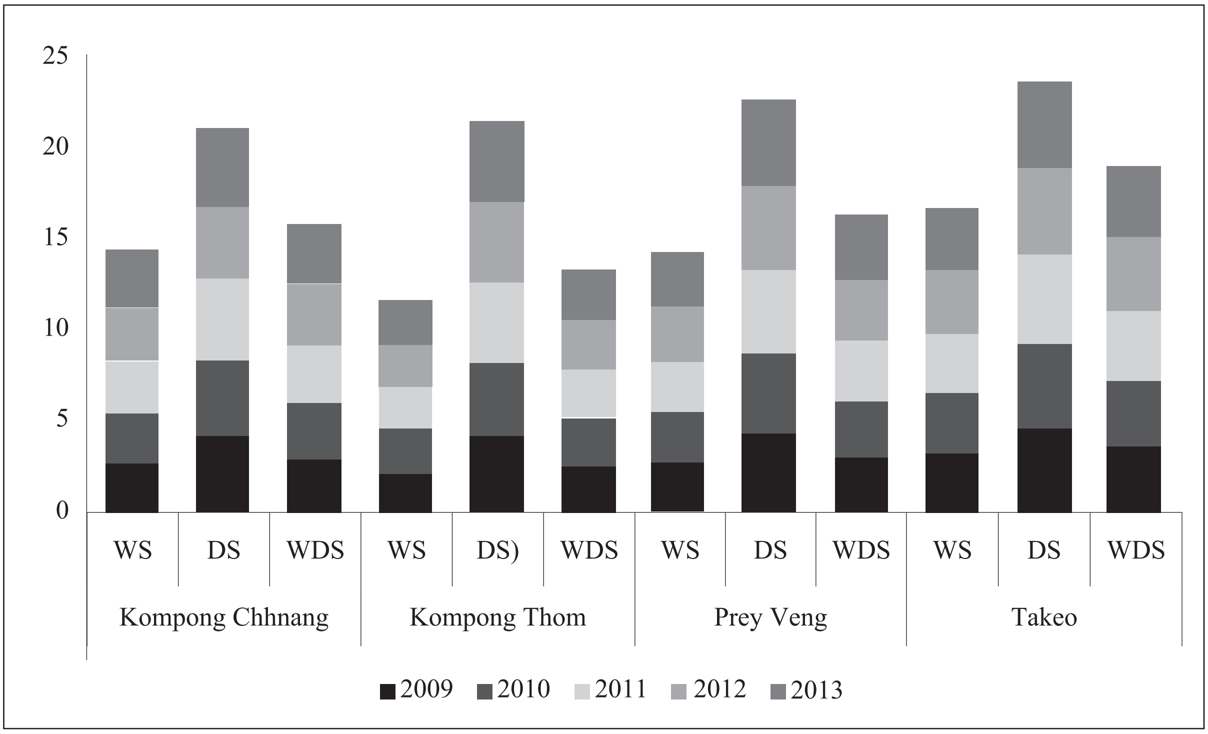
Note: WSP: Wet Season Production
DSP: Dry Season Production
HA: Harvested Area

Figure 5: Size of cultivated rice land in 2010



Source: NCDD 2010

Figure 6: Yield 2009-2013 (tonnes per ha)



Source: MAFF 2013

Note: WS: Wet Season
DS: Dry Season
WDS: Wet and Dry Seasons

The yield of wet and dry season rice differs according to MAFF. The range of yields in the wet season is from 2 to 3.5 tonnes per ha and in the dry season from 4 to 4.8 tonnes per ha (Figure 6). While this variation is from season to season, there is also a distinction from one maturity to another. From discussion and interviews in the selected communes, the yield of early maturity varieties is higher than others. In Krapum Chhuk commune, the yield of IR85 is up to 7 tonnes per ha. 504 and IR 66 grown in Ou Kanthor commune are also reported to have high yields, ranging from 5 to 7 tonnes per ha. This high yield is correlated with high chemical fertiliser application and sufficient water supply. Medium maturity varieties have medium yields averaging around 3 tonnes per ha , while later maturity varieties yield around 2 tonnes per ha. A difference is also described by farmers between transplanting and broadcasting (see the findings section).

6. Findings

6.1. Current SRI practices

SRI practices differ according to agro-ecological area and socio-economic conditions. SRI in rain-fed and irrigated areas is not distinct since irrigated rice plots are not equipped with drainage systems, so farmers find it hard to drain water from their fields. Not all principles and steps of SRI have been practised because farmers adjust to their own circumstances. SRI has been applied differently even within the same village (Table 4).

6.1.1. Variety selection

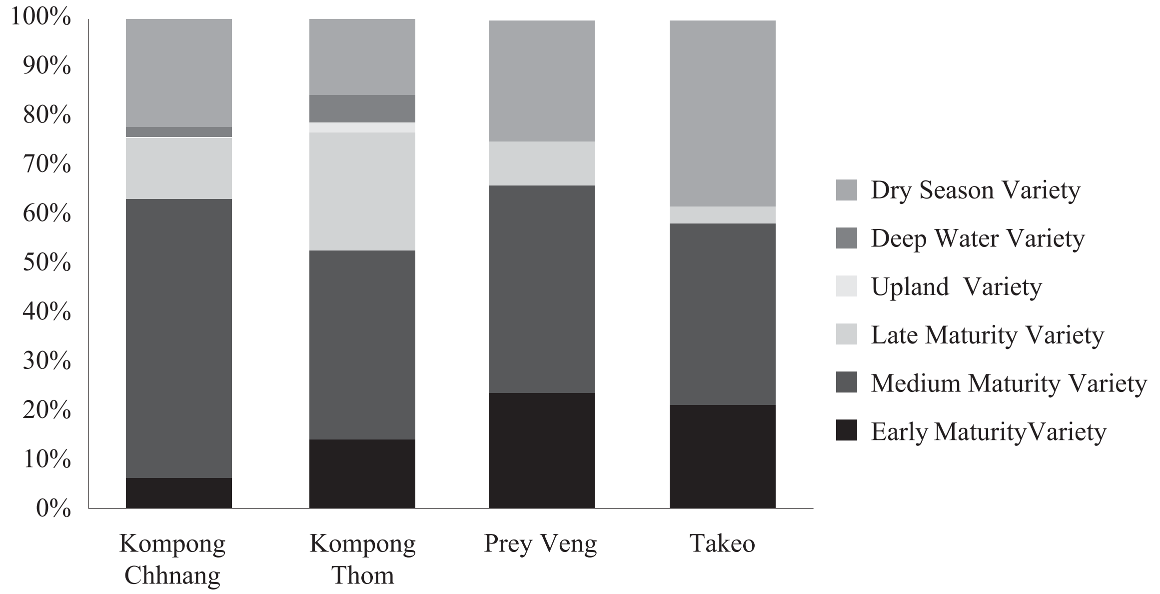
Farmers from the selected communes use the three varieties; however, based on the discussion, modern varieties are preferred for early wet and dry season. Modern varieties includes IR 66, variety 504,[11] and variety 85,[12] improved traditional varieties includes Raing Chey, Phka Rumduol, Somaly and Phka Malis, and traditional varieties comprises Kronhol, Neang Khon and Neang Tom. In the main wet season, they use both traditional varieties and improved traditional varieties. Southern Cambodia has the largest part of the 41 percent of total rice area occupied by modern varieties; the northwest has 27 percent and central Cambodia17 percent of the area occupied by traditional varieties and improved traditional varieties (Wang 2012). The main reasons for selecting varieties in the visited communes are market value, agronomic conditions, eating preferences, yield, risk and resistance. Specifically to cope with climate variability, farmers have changed from photoperiod-sensitive late maturity to photoperiod-insensitive early maturity varieties. When asked why they did not choose 10 recommended varieties, they reported that they do not have market value and some of them are not suitable for their conditions.

Prey Veng has not only the largest cultivated rice area among the four visited provinces but also among other provinces (MAFF 2013). In the wet season, MMV has the largest share of the total cultivated area in the four provinces, followed by EMV (Figure 7). In the dry season, Takeo and Prey Veng have the largest cultivated areas thanks to irrigation systems in theses provinces. Groundwater is also used in each cropping season in the provinces, according to the Commune Database online of NCDD from 2008 to 2010.

11 This variety is originally from Vietnam (Wang 2012).

12 This variety is originally from Vietnam. It might be TH85 released for both rain-fed and irrigation-receding conditions (Wang 2012).

Figure 7: Rice varieties and cultivated area in the visited province, 2013



Source: MAFF 2013

Box 1: Phka Romduol rice production in Prey Veng

In the last few years, farmers in Prey Veng province started to pay attention to Phka Romduol variety since it has market value (1250 riels/kg of wet rice) and costs less to produce. It is also a fragrant rice and appropriate to the agro-ecological system of the province. This variety accounted for 23.29 percent of the total wet season cultivated area in Prey Veng in 2013; 65 percent of villages in the province are producing this variety. The cultivated area increases from year to year.

Compared to IR varieties which yield 4.6 tonnes per ha, its yield is just 3.2 tonnes per ha; however, Phka Romduol gains a much higher profit rate since the price of IR is less than that of Phka Romduol.

Phka Romduol is a photoperiod-sensitive MMV grown from May to November. According to the interview with PDA, this variety can be grown from October, November or December because there is possibility of rainfall in December or January, and farmers can supplement that with water from wells.

Source: PDA Prey Veng 2013

6.1.2. Seed preparation

Most farmers have their own ways of preparing seeds for broadcasting and transplanting. Some farmers have updated their methods as they learn techniques from training provided by PDAs/ DAOs and NGOs. Seed preparation practices are set locally. Farmers of Chong Ampil and Krapum Chhuk have experimented with their seeds in wet and dry fields. The seeds are soaked in water for one night and incubated for another night, then broadcast on saturated/muddy soil. But if the soil is not saturated, they might just broadcast dry seed. Doing this involves the risk that rain does not fall in time. These cases apply in non-irrigated or rain-fed fields; farmers of Ou Kanthor have a slightly different way of preparing the seeds because they can access irrigation water. There are also two ways: soaking and moistening seeds. The seeds are soaked and incubated as usual (one day for soaking and another for incubating) to broadcast into muddy fields. In this case, they have to drain water from the fields before they broadcast the seeds. If they do not drain the water, they just moisten the seeds and broadcast directly. People from other communes also report having tried different ways of preparing seeds on various types of soil in their communes. They do not apply the exact technical methods mentioned in the training but rather a mix between the training and what they have practised previously.

For transplanting, a nursery bed is prepared. Although some farmers receive training on how to prepare the bed, they still use customary ways. They adopt only some steps in the recommended practices, combining them with their local knowledge and conditions.

6.1.3. Field preparation

Ploughing, harrowing and levelling make the field ready for either transplanting or broadcasting. Usually, ploughing is done twice harrowing and levelling once. However, the frequency depends on the type of ploughing means and methods of sowing. Usually, the ploughing is done twice if farmers can afford machinery or if they use animals. In Krapum Chhuk, they plough only once by machinery because it is costly. One ploughing is applied in Ou Kanthor if the seeds are to be broadcast, two ploughings if transplanting is planned. Farmers report having changed their cropping method because rainfall is irregular. They do not wait until the amount of rainfall is adequate, as before, but now start immediately after the first rain of the wet season.

6.1.4. Seedlings

Among the eight communes, only four employ transplanting (Table 4). The age of the seedlings depends on the varieties and water availability. Farmers learn that young seedlings are productive and try to use young ones as much as they can, but it also depends on water availability. They start to transplant once the fields are moist, and if they are rainfed, the onset of rain is very important: if it comes on time, they can transplant the young seedlings but not if the rainfall is late. The age of the young seedlings averages 15 to 30 days,.

6.1.5. Planting methods

Transplanting and seeding depend on local conditions and practices. Transplanting is used for resistance to pest and weed. In Thlok Vien commune, farmers employ transplanting to prevent weeds. If they broadcast the seed and there is no rainfall, weeds grow very quickly. In Sala Visai commune, farmers transplant because the variety they use gives a high yield if transplanted. Transplanting is also compatible with soil conditions in the commune. In some areas, farmers use broadcasting because they do not have to spend time checking the field. Now, because of labour shortage, farmers have changed from transplanting to broadcasting although they realise that the yield is lower. Some farmers who transplant have adopted SRI practices including transplanting in rows, selecting vigorous seedlings, transplanting one to three seedlings per hill and using young seedlings. Among the visited communes, Thlok Vien has more adopters of these practices because CEDAC has been working in the commune for a long time. However, people in this commune have been testing broadcasting to save labour.

Those who broadcast use an amount of seed different from the recommendation based on their localities and varieties. Some of them who use Vietnamese varieties in Takeo, Prey Veng and Kompong Thom conduct their own tests of how much seed is needed.

Table 3: Planting methods

Province	Commune	Broadcasting	Transplanting	Organic Fertiliser (cart/ha)	Inorganic Fertiliser (kg/ha)
KCH	TV		X	14	30
	TKS	X	X	16	75
KTH	OK	X		NA	200
	SV	X	X	15	100
PV	CA	X		15	150
	TH	X		NA	200
TK	KC	X		NA	350
	TTKC	X	X	20	NA

Source: Interviews and discussions 2014

6.1.6. Soil amendment

Organic fertilisers are highly recommended for high yield. Compost is applied in all communes except Ou Kanthor, Theay and Krapum Chhuk, where farmers think it takes too long to produce good results and they find it hard to transport to their distant and dispersed fields. The amount of compost recommended varies with soil type; however, the amount applied is lower than that because farmers apply only as much as they can manage.

In organic fertiliser is also suggested if organic fertilisers are not sufficient or applicable. With a lot of training, some farmers know what types and how much to apply to various types of soil. Even so, if farmers cannot afford to buy fertiliser, they will not apply it as recommended. Other farmers apply a lot of in organic fertiliser without knowing how much should be applied, believing that this will give them a higher yield. In Thlok Vien, where CEDAC has long been working, farmers have gained more knowledge of SRI practices and some even produce organic rice to be sold to CEDAC.

6.1.7. Water management

Irrigated rather than rain-fed fields are better because, in SRI principles, the water level is defined in each phase of rice development, and fields have to be even. In rain-fed systems, farmers find it hard to sustain water in the fields if they do not have ponds or streams in addition to rainfall. Farmers whose lands are near ponds or streams can drain unnecessary water out of the fields. Agricultural training by either PDA or NGOs gives farmers abetter understanding of the level of water needed for rice development. They seem to adopt it well if there is enough water in their fields. In irrigated fields, the water level is also a problem if there is no drainage system. However, farmers drain water through neighbouring fields. However, in areas where irrigated water is charged for, farmers rarely let water flow from their fields. This case happens in Ou Kanthor, where water costs around USD110 per cropping season. In areas where water is limited, farmers do the same. Farmers in Krapum Chhuk and Trapeang Thom Khang Cheung reported not draining water because the water in the reservoirs is limited. Fields in the visited communes are reported to be uneven. Farmers who can afford to use machinery to level the fields have no problem, but some in Krapum Chhuk and Chong Ampil cannot afford it.

Inspection of water levels in the fields is based on cropping method. Broadcasting farmers irregularly or rarely check the field, but for transplanting, they have to inspect water levels and care for the field carefully. However, for broadcast EMV, they will do the same as for transplanting.

6.1.8. Weed, pest and disease management

As with water management, farmers will regularly check for weeds if they transplant. Weeding is done manually, and some farmers apply herbicides. Weeds grow in some specific soils. For example, in Ou Kanthor, farmers have to spray herbicide immediately after broadcasting seed. Based on local experience, farmers know when to start weeding.

Table 4:Practices and adoption or adaptation

Practices	Details	KCH		KTH		PV		TK		Note
		TV	**TKS**	**OK**	**SV**	**CA**	**TH**	**KC**	**TTKC**	
Variety selection	High yield	√			√	√	√	√	√	Varieties selection also based on labour demand, adaptation to erratic rainfall and drought, water availability and local custom.
	Tolerant to pest/ drought/flood	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
	Ecosystem suited	√	√	√	√	√	√	√	√	
	Market demand	√	√	√		√	√	√	√	
Seed preparation	Seed preparation	√	√	√	√	√	√	√	√	Farmers adopt and adapt the practices based on soil type, water availability and local custom.
	Nursery preparation	√	Δ		Δ				Δ	
Field preparation	Ploughing	√	√	Δ	√	Δ	Δ	Δ	√	These practices depend on whether farmers use machinery or animals. They can double the ploughing if animals are used. Levelling is done manually or mechanically depending on means of the farmers.
	Harrowing	√	√	√	√	√	√	√	√	
	Levelling	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
Seedlings	Age of seedlings	Δ	Δ		Δ				Δ	Age of seedlings depends on water availability.
	Field preparation	Δ			Δ				Δ	
Planting methods	Direct seeding		Δ	Δ	Δ	Δ	Δ	Δ	Δ	Practice selected due to water availability, labour demand, soil type, complexity of the practices and local innovation.
	Transplanting	Δ	Δ		Δ				Δ	
Soil improvement	Organic fertiliser	Δ	Δ		Δ	Δ			Δ	The application does not follow the recommended rate of CARDI due to limited access to information, people's mindset, affordability and availability.
	Inorganic fertiliser	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
Water management	Water storage				Δ	Δ	Δ			Other water storage options besides rainfall and irrigation, canal or reservoir can be ponds and wells. They are dug based on affordability, soil type and access to information. Water availability and canal structures affect water flow and depth.
	Water depth	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
	Intermittent irrigation	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
Weed, pest and disease management	Weeds	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Whether farmers choose biological, manual or chemical means to deal with these issues depends on extent of the phenomenon, and available technology.
	Pests	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	
	Disease	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	

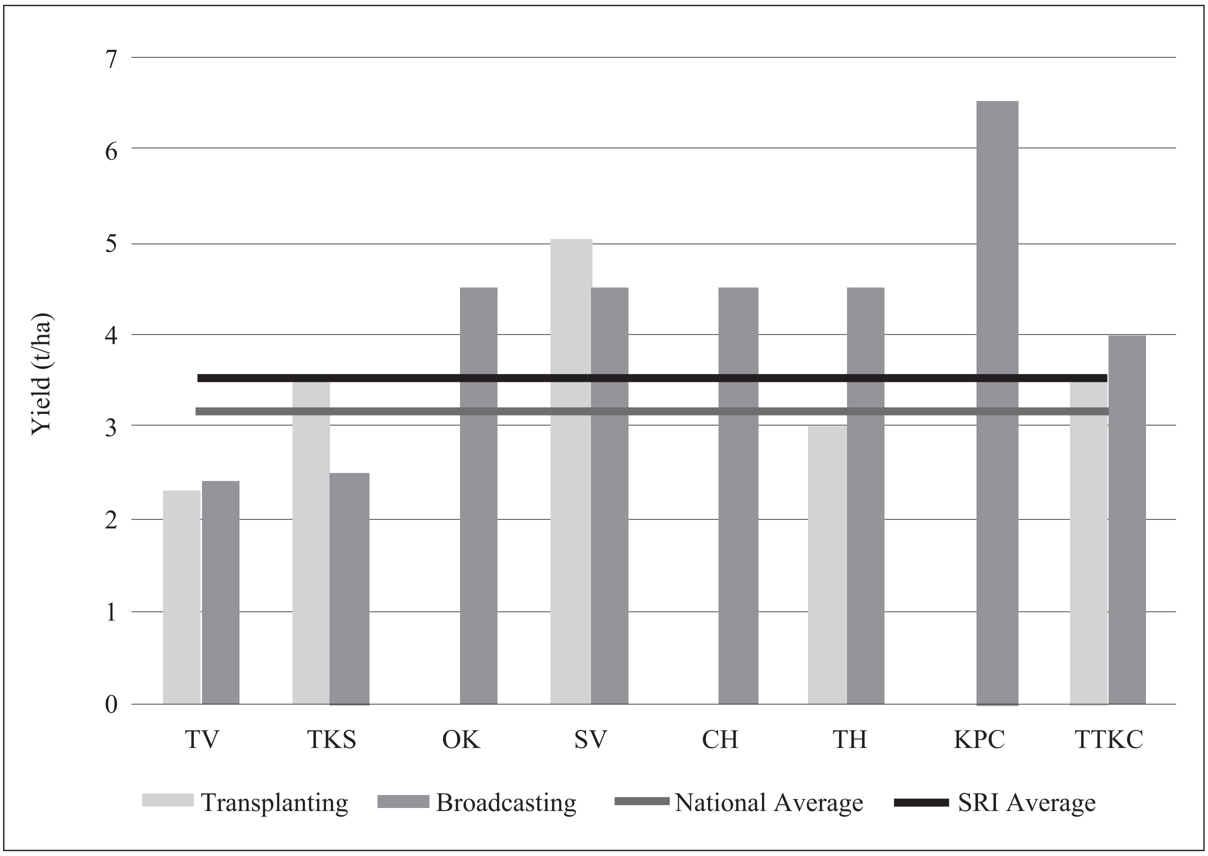
Note: √: Fully adopted/adapted

Δ: Not fully adopted/adapted

From Table 5, the most common practice in the SRI package is variety selection. Within the selection, the market is the most popular criterion. Other practices are only partially adopted.

The yield of SRI adopters, employing either transplanting or direct seeding, was higher than the national SRI average in 2009 and the general average in 2013 (Figure 8). Yield and the amount of fertilisers applied are correlated. In Krapum Chhuk, where the most inorganic fertiliser is applied, the yield is highest, but it should be also noted that the soil in the area is fertile. In Thlok Vien, where soil is not so fertile, and there is less application of organic fertiliser, yields are lower.

Figure 8: Comparison between yield of each planting methods



Source: Interviews and discussions201;Ngin 2010; MAFF 2013

6.2. Factors affecting adoption

The interviews and discussions identified many factors affecting farmers' adoption of SRI. A summary of each factor and location where it occurs is in Table 6 while that of factors in each practice in Table 7.

6.2.1. Socioeconomic factors

- **Labour**

  Using smaller amounts of seeds or seedlings has reduced labour in some areas that formerly used a lot of seeds or seedlings. If seedlings are reduced, the labour required for transplanting also decreases. If the labour is available, farmers will level land since they acknowledge that a level field has better potential for water management, fertiliser application, high yield and harvesting.

SRI requires intensive labour from the beginning of cropping till harvesting: manual levelling the land, transplanting, inspecting water levels, manual weeding. The most intensive task is transplanting. Previously, people exchanged labour with each other but not anymore. So people just take up some or no SRI practices. Moreover, not only are there not enough people for cultivation, but also it is hard to find a person from each household to join training on SRI. That trainee needs to be energetic and have strong commitment. Not-so-young trainees are easily bored.

- **Land**

  Farmers who own many land parcels do not care about adopting SRI practices, and if lands are far from each other or from their homes, people also do not consider the practices, especially organic fertiliser application; they find it hard to transport fertiliser to those fields. Time is also a major constraint on checking water level and weeding for distant fields.

  SRI with transplanting is mostly employed by people who own small plots, since taking care of a small plot is easier. However, people apply transplanting on part of their field either to test the effects or to avoid losses from shocks. In Tang Krasang, where people are trying the recommended transplanting, which they have just learnt from training provided by the PDA.

- **Mindset and local practices**

  Mindset and local practices are of the most prominent challenges for changing farmers' behaviour. Once they used to transplanting clumps of seedlings, it is hard to alter this. The mindset and practices affect the adoption of all new methods.

  The positive side is that, once people are trained and their knowledge increases, they adopt what is best for cultivation. This applies to many practices. Some farmers of Sala Visai, Trapeang Thom, Khang Cheung and Thlok Vienhave taken up transplanting methods and practices requiring less seed because their mindset has been transformed through training, local innovation and dissemination from NGOs or state extension services.

6.2.2. Physical factors

- **Water**

  People would adopt the practices easily if they had access to water for the whole cropping period. They can use fewer seeds and transplant young seedlings without any concerns for drought or weeds. The various water storage options available are concentrated only in some areas. Prey Veng and Takeo have the most access to irrigation. They also can access groundwater if surface water is not sufficient. The limited amount of water could also push farmers to adopt practices requiring less water and other feasible SRI practices. When farmers face a small dry spell and cannot access water, applying organic fertiliser helps reduce evaporation and retain soil moisture.

  Water can be a negative factor for adoption if it is not available. A large proportion of cultivated land in Cambodia is rainfed, making it hard to apply SRI. The onset of rainfall has not been regular in the last 10 years, and climate-related information is not accurate and accessible, making farmers feel reluctant and risk-shy. People cannot afford to follow the recommendation on pond establishment. There seems to be an absence of local initiative in identifying water storage options and mobilising local resources to establish it. Without access to water, people tend to ignore nearly all of the SRI package. Water management practices are not feasible because of limited water amounts.

- **Inputs**

  Access to agricultural inputs is another determinant of the adoption of SRI package practices. Pure seeds, organic and inorganic fertilisers and machinery allow farmers to put more effort into upgrading or justifying their current cultivation practices. With these necessary inputs, some farmers even conduct experiments to test what amount of each inputs and what method of application is best suited to the local ecosystem. Farmers report using recommended amount of seeds if they are equipped with drum seeders and rotary weeders.

  Some farmers of Takeo and Prey Veng claim that if they owned either four-wheel tractors or hand tractors, they would apply what has been recommended to prepare the field, specifically land levelling, which is the most important step. Fertilisers are another major input and people understand that they are crucial in increasing productivity but as long as they cannot afford or find them, they still apply whatever they can. Some farmers cannot afford to buy pure seeds since they are high price. The supply of these seeds from either the AQIP seed company, CARDI or private business is reported to be limited. Most of the farmers in the visited communes produce their own rice seeds without purification, and they are used for several generations. There are some farmers involve in seed production supported by HARVEST in Kompong Thom, CARDI in Takeo and PADEE in Prey Veng.

- **Access to markets**

  Markets can also be a factor. If markets are accessible, people will do whatever is necessary to get a high yield despite challenges. In Thlok Vien, people adopt organic SRI because CEDAC buys rice from them at a higher than normal price. In Chong Ampil, farmers even try to innovate with recommended practices to adapt to local conditions so that they get a high yield to supply the accessible market. In Ou Kanthor, farmers pay USD110 per cropping season to get water for rice cultivation since IR504 has a market value and the middleman goes to the rice fields and buys the produce immediately after harvest. People are eager to learn and test new practices to boost productivity when the market is there.

  If the market incentive is absent, people will adopt good practices at first but then quit. People in Theay grew Romduol, which is a high yielding variety suited to local conditions, but stopped using it because there is no market incentive (it is sold to middlemen at a price lower than that of the normal market). This happens since people there do not collectively grow this variety, so the supply is less than the demand of the middlemen, who then refuse to collect it making the price go lower than usual.

6.2.3. Technological factors

- **Access to technical information**

  Before farmers select which practice to adopt, they need sufficient technical information. They have to know what practices will help them cope with extreme events while enhancing productivity. Farmers in communes that usually receive information and training from PDAs, and NGOs know what they should do and this links them to recommended practices. Thlok Vien, which receives both information and training from CEDAC, does not ask for more, but the other seven communes do, because only a small group of people have received them. Farmers there did not know the amount of seeds required for direct seeding in their agro-ecological zone. However, whether and to what extent they adopt SRI depends on other factors as well. Some farmers do not know that such practices are available and feasible.

How information is shared with farmers is also a factor. Today, the Farmer Field School plays an important role in diffusing information and knowledge to farmers. Farmers who gain information and knowledge from the school can also adapt practices for their localities. But this school needs support from the state or NGOs. Project supported byCEDAC, CARDI and PADEE are establishing such schools. The schools provide information, boost knowledge, foster local innovation and offer other support to farmers. They then adopt and adapt the practices confidently.

The nature of information affects acceptance. The easier the practices, the more they are adopted. This is what people of Trapeang Thom Khang Cheung, Chong Ampil, Krapum Chhuk and Ou Kanthor reported as a major challenge. Interviews and discussions reported that farmers would accept only easy practices that are not too technical.

6.2.4. Institutional factors

- **Access to rural institutions**

  Access to rural formal and informal institutions influences whether farmers adopt SRI. Formal institutions including PDAs, DAOs, CARDI and NGO projects provide extension services to farmers. Equipped with the information and support provided, farmers take up the practices confidently. Farmers from all the visited communes mentioned the availability of resource persons providing technical information from the formal institutions. They said that there are no village persons to go to when they have questions. Some farmers even quit using the practices because they felt ignored. This is another obstacle facing both state agencies and NGOs.

  Because these institutional arrangements are limited, some farmers depend on informal institutions in the community such as FWUCs, agricultural cooperatives, saving groups and social networks. Through these, they can share information and knowledge and work collectively and supportively. Through the Roluos FWUC of Ou Kanthor and Farmer Field School of Sala Visai, farmers learn from each other the best localised practices. They also share information based on neighbourhood or kinship relations. Agricultural cooperatives in Krapum Chhuk commune give loans and inorganic fertiliser, and buy milled rice of members.

6.2.5. Agronomic factors

- **Risk**

  Risk can attract farmers to take up the practices regardless of conditions. When climate-related changes are coming, people will try any means to sustain their crops. To cope with drought in the rainy season, people in Theay and Thlok Vien change from MMV to EMV and apply more green manure rather than chemical fertilisers to enhance soil moisture. Finding alternative water sources such as ponds in Theay commune shows how risk motivates people to consider the recommended water storage for rain-fed and drought-prone areas. Soil type, local weather and ecosystem in combination with the number of parcels of land influence the way people choose practices. If high yield and reduced risk to flood, drought and pests are expected, farmers will confidently take up the practices. The best example of this is the uptake of field preparation in Sala Visai. Once farmers apply this, weeds are reduced.

By contrast, risk also prevents farmers adopting SRI. Since they become used to broadcasting many seeds and transplanting old seedlings to deal with disasters, they think it is too risky to reduce the amount of seeds and use young seedlings. Because they have to bear any losses on their own, they are reluctant to adopt the practices. This happened to farmers in Tang Krasang commune.

- **Yield**

  Increased yield from applying the practices motivates farmers to adopt the whole set. Farmers from the visited communes realised that SRI practices would increase productivity. In Sala Visai and Chong Ampil, some farmers who localised the practices gained more yield, which repaid their commitment and efforts.

  But if the yield is just a bit higher than from conventional practice, farmers do not adopt SRI, which happened with some farmers in Trapeang Thom Khang Cheung. In some cases, the yield is a lot higher but the cost is also higher, which makes SRInot so profitable and, they refuse to adopt the practices. The cost is high if they hire people for transplanting.

- **Weeds**

  Broadcast seed is vulnerable to weed and will be more vulnerable if farmers broadcast less than recommended in SRI. However, they first adopt what amount is recommended and then adapt the broadcast amount to fit with local condition. They apply the seeds based on rice variety and local agro-ecological conditions. Sala Visai reported less weed problem if they practise field preparation. Young and strong seedlings are transplanted in Thlok Vien because of weed problems if broadcasting is used.

Table 5: Summary of factors affecting adoption of SRI

Communes	**Labour requirement**	**Land (number, size, and distance)**	**Mindset**	**Access to Water**	**Access to Inputs**	**Access to Market**	**Access to Information**	**Extension Service**	**Rural Institutions**	**Risk**	**Yield**	**Weeds**
TV	-/+	-	-	-		-/+	+	+	-/+	+	+	+
TKS	-		-	-/+	-/+		-/+	-/+		-	+	
OK		-	-/+	-/+	-/+	+	-/+	-/+	+	+	-	+
SV	-	-		-/+	-/+	+	-/+	-/+			+	+
CA	-		-	-	-/+	-/+	-/+	-/+	+		-	
TH	-			-/+	+	+	+	-/+	+	+	+	
KC	-	-		-/+	-/+	-/+	-/+	-/+	+		-	
TTKC	-/+	-	+	-/+	-/+		-		+		+	

Note: (-) factor discourages farmers from adopting SRI.
(+) factor encourages farmers to adopt SRI.

Table 6: Factors affecting adoption of each SRI practice

Practices	Details	Labour requirement	Land (number, size, and distance)	Mindset and local practice	Access to Water	Access to Inputs	Access to Market	Access to Information	Rural Institutions	Risk	Yield	Weeds
Variety selection	High yield				-/+	-/+	-/+	-/+	-/+		-/+	
	Tolerant of pests, flood and drought		+	+	-/+	-/+	-/+	-/+	-/+	+		+
	Ecosystem suited		+	-/+				-/+	-/+	+		
	Market demand		-/+		+	-/+	+	-/+	-/+			
Seed preparation	Seed preparation		-/+	+	-/+		+	+		+	+	
	Nursery preparation		-/+	-/+	-/+		+	-/+			+	
Field preparation	Ploughing		-/+			-/+	+		-/+		+	+
	Harrowing					-/+	+				+	
	Levelling	-/+	-/+			-/+	+	-/+			+	+
Seedlings	Age of seedlings			-/+	-/+		+	-/+		-	+	
	Field preparation		-/+	-/+	-/+		+	-/+			+	
Planting methods	Direct seeding	+	+	-/+	-/+	+	+	+			+	-
	Transplanting	-/+	-/+	-/+	-/+		+	-/+	+		+	+
Soil improvement	Organic fertiliser	-	-/+	-/+	-/+	-/+	+	-/+	+	+	+	
	Inorganic fertiliser		-/+	-	-/+	-/+	+	-/+	+		+	
Water management	Water storage		-/+		-/+		+	-/+	-/+	+	+	
	Water depth	-		-	-/+		+	-/+		-/+	+	
	Intermittent irrigation	-		-	-/+		+	-/+		-/+	+	
Weed, pest, and disease management	Weed	-/+	-/+	-/+	-/+	-/+	+	-/+	-/+	-/+	+	-/+
	Pest				-/+		+	-/+	-/+		+	
	Disease				-/+		+	-/+	-/+		+	

Note: (-) factor discourages farmers from adopting the practice.
(+) factor encourages farmers to adopt the practice.

7. Discussion

7.1. Extent of adoption or adaptation

Based on their current practices, farmers mostly adopt and adapt practices that they think are beneficial and feasible. Though some practices are proved effective, they still choose which practices to take up. The adoption of SRI package is not a must (Schweisguth 2013). Each practice potentially enhancing productivity and if a significant production growth is expected, all steps and practices are needed (Appocciolo 2012). As reviewed by Schweisguth (2013), research on specific SRI practices shows that each practice is localised and depends on local conditions. In the visited communes, even if people adopt only some SRI practices, they still get satisfactory yields. What should be learned from these reviewed practices is the need for adaptation of the recommended practices to the agro-ecological conditions or localisation of the practices. SRI principles and practices keep evolving, and SRI becomes an agro-ecological approach or innovative concept (Stoop 2014; Uphoff 2007). Regarding fertiliser application, there are many studies by CARDI comparing recommended rate, control and farmer practice (CARDI 2010, 2011, 2012). They find that recommended rate is the most effective rate in enhancing productivity. But when CARDI experimented in 2012 testing control, recommended rate and verified recommended rate for Proteah Lang soil, the verified recommended rate is found is the most effective rate (CARDI 2012). It can be inferred that each soil type in different agro-ecological conditions requires localised practice, and the recommended practices themselves require localisation.

7.2. Factors affecting adoption

Most results on factors influencing farmers' adoption of SRI practices are similar to those of the literature. However, the details on some variables are different and were not found in previous studies on SRI.

Findings on labour requirement for cultivation; access to water, inputs, market, technical information and rural institutions; yield; risk; and weeds are consistent with previous studies on SRI either in Cambodia or outside. Various studies note labour intensity as the most challenging factor in promoting farmers to adopt and adapt the practices (FAO 2012; Ly et al. 2012; Barrett et al. 2004; Latif et al. 2005; Moser and Barrett 2003; Tsujimoto et al. 2009). This study also found labour intensity obstructing farmers from adopting and adapting the practices. However, the most labour intensive practice is transplanting, and nearly all of these studies exclude direct seeding. Ly et al. (2012) compared conventional, SRI (transplanting) and direct seeding and found that direct seeding has the lowest labour requirement, followed by SRI transplanting that uses fewer seedlings. The positive side found in this study, consistent with others, is that using fewer seeds reduces labour for both transplanting and direct seeding (Ly et al. 2912; Tsurui, Yamaji and Suk 2011). Access to water, inputs, markets, technical information and rural institutions are generally seen as either motivations or challenges to farmers taking up not only SRI, but also climate-smart agriculture and sustainable agriculture (McCarthy et al. 2011; Laksana et al. 2013; Yang 2011; Feuer 2008; Ly et al. 2012; Beadman 2009; Rappocciolo 2012; Lamboll and Nelson 2012).They are consistent with this study as well. Increased yield motivates farmers not only adopt to but also to adapt the practices to suit the locality, and this is also a common factor in the literature (Mao,Tongdeelert and Chumjai 2008; Beadman 2009; Tsurui, Yamaji and Suk 2010). Risk of climate variability and change would either encourage or discourage farmers to select the practices. It is an encouragement if the practices are feasible while it is not if they have to bear all the losses resulting from the risk. This finding also supports various reports on how SRI deals with climate change. SRI adapts to the variability and change through reducing water demand and being resistant to drought, flood, pests and disease (Africare, Oxfam America and WWF-ICRISAT Project 2010; Ches 2012; Uphoff 2005). Both transplanting and direct seeding are prone to weed infestation and depend on local agronomic and agro-ecological conditions. These are also well documented in Cambodia and other countries where SRI is implemented (Pathak et al. 2011;Farooq et al. 2011; Ly et al. 2012).

Migration from rural Cambodia, which leaves mostly elderly people in the village, impedes not only the adoption of good agricultural practices but also information sharing on them. This phenomenon is not found in the literature. The number of land parcels and their location determining adoption are also not found in studies related to SRI. McCarthy et al. (2011) and Lamboll and Nelson (2012) report that land tenure is a challenge pushing farmers to adopt climate-smart and sustainable agriculture, and this applies to poor farmers. Uphoff (2008) claimed that SRI adoption is challenged by “mental and attitudinal” obstacles because farmers first see the labour intensity of the practices. This is perhaps not the same idea as in this study, since mindset and local practices refer to what people have been doing and reluctant to change; it is not only labour but changing their method of cultivation. Many reports claim that the increased yield attracts many farmers (Mao, Tongdeelert and Chumjai 2008; Beadman 2009; Tsurui, Yamaji and Suk 2010). But for this study, an increased yield that isnot so profitable compared to conventional practice prevents farmers considering SRI. This seems to be a different scenario from those reports.

8. Conclusion and recommendations

SRI is a method for increasing rice productivity by improving the management of plants, soil, water and nutrients. These practices contribute to healthier soil and plants through greater root growth and the nurturing of soil microbial diversity. It has been found to be a sustainable rice farming technology that could build the capacity of smallholders to withstand climate change and increase their crops’ resilience, increase food security as a result, increase the income of smallholders and rice yield and improve the quality of rice.

8.1. Gaps in practice

Farmers select only the practices that they think are feasible and beneficial. Feasible means easy to implement and in keeping with local agro-ecological and socioeconomic conditions. They need a complete set of practices and support. The findings also suggest that, once farmers are keen on upgrading their production, they not only adopt the practices but also adapt them to fit local conditions. They do not need a complete set of those practices. This proves effective in the current circumstances of rural Cambodia, where access to necessary elements for cultivation in the context of climate change is still limited.

The gaps between ideal or recommended practices and current implementation are identified in this study. Factors contributing to these gaps are also presented. Efforts to bridge the gaps are urgently required. While national efforts are going on, local efforts that do not depend on external support are also important in helping farmers cope with climate variability and change.

8.2. How to fill gaps or increase adoption and adaptation?

This can be done through various levels and institutions. It is suggested to be administered simultaneously to ensure the spread and on-time adaptation to variability and change.

8.2.1. Local communities

In order not to depend on external support, local resource mobilisation is needed. One local resource crucial for climate change adaptation is collective action: people working together to cope with specific phenomena. People's financial or labour resources might be needed to deal with an event. Such action can share technical information, foster local innovation in dealing with weeds and adapting practices, facilitate access to market and inputs, identify local water storage options and share risks and labour. It can also diffused into rural institutions including agricultural cooperatives, FWUCs and saving groups.

Farmers have to understand well the importance of this local resource so that they are motivated to build this relation. It needs support from government and NGOs at first to spread local resource mobilisation.

8.2.2. NGOs

NGOs that act as field extension agents have generally used training of trainer, Farmer Field School, field days, field demonstrations and field visits to transfer technical information and knowledge to farmers and other field agents. These are quite acceptable to farmers and need to be expanded. NGOs should also discuss coverage with state departments involved in agricultural extension since they should be complementing each other so that the most needy and vulnerable areas are targeted.

Since local adaptation/innovation takes a great foundation in helping farmers deal with climate-related issues, NGOs should focus more on this system. They should also first work closely with subject matter specialist departments and institutions[13] to identify suitable technology and procedures such as agro-ecosystems analysis[14]for each agro-ecological condition. The participatory methods available in the agricultural extension system, including participatory assessment and planning, participatory technology development and participatory training extension, are effective in transferring knowledge, experience and information to farmers. Support for the local adaptation/innovation could be administered through participatory experimentation with recommended practices to find the most suitable ones and mobilising local resources to make sure the innovation works best and for everyone.

NGOs should also consider the complexity and technicality of each practice since they contribute to farmers' rejecting the practices. Simplification and adjusting to local knowledge help farmers to understand the practice.

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13 According to Mak (2012) subject matter specialist consist of MAFF's technical department, CARDI and the Royal University of Agriculture. Production, technological research and development, regulation support, human resources development and technical backstopping to provincial and district extension are the responsibilities of these departments and institutes.

14 This is "a participatory needs assessment methodology to identify priority farmer problems and development opportunities at the commune level" (Mak 2012).

Since social issues are embedded in technology adoption and adaption, NGOs should consider this and include these issues in their programmes and projects. Social solutions are time consuming, so, if possible, the timeframe should be longer to make sure the social issues are solved.

Adoption is linked with the market and current market information sharing via website and text messages. NGOs and government through field extension agents should provide advice on ways such as contract farming and local community establishment in which farmers can connect to the market by themselves. The information should be connected with the dissemination of SRI practices so that a complete set is shared with farmers. It might be more effective if training were also provided on financial management and leadership.

8.2.3. National and sub-national government

The current agricultural extension, including priority programmes,[15] actors[16] and participatory methods, is very effective on paper while, based on this study, the practical implementation is still limited due to insufficient human resources and funds. Taking the opportunity of climate change issues attracting donors, funds should be granted to enhance the current extension system.

SRI is nationally recognised as a practice that can help farmers adapt to climate change and it has been in the national spotlight. Hence what to do next is to implement SRI-related strategies. The government should also expand the coverage of SRI by building the capacity of farmers and service providers, transferring and disseminating improved technology to farmers. Farmers still require technical and financial support from government as well as civil society and development partners to expand and sustain SRI practice.

SMS departments and institutions are quite important in transferring technologies and practices to field extension agents. They need enhanced R&D to ensure that the most suitable practices are recommended for each agro-ecological condition.

State field extension agents are reported to be too few. Current village extension agents are veterinary volunteers. The government should focus on this issue by not only increasing the number of the village agents but also mobilising local human resource to work as a group of local extension.

The system for rewarding for best SRI adopter is very encouraging. It should be promoted so that farmers are motivated and supported in adopting the practices. SRI should be flexibly implemented according to local conditions.

Considering local resource mobilisation as another type of available resource to be used for sharing the transferring the technical information and knowledge relating to SRI practices should be done since it can at least increase the current coverage of the state. Sub-national government should share information on how local resources should be used.

15 The programmes include participatory assessment and planning, participatory technology development, participatory training and extension, extension materials development and dissemination, farmer organisation development, and household food security (Mak 2012).

16 Actors: PDA, DAO, Department of Agricultural Extension, subject matter specialist departments and institutes and field extension agents (Mak 2012).

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