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Strengthening climate resilience of rural communities by co-producing landscape-specific integrated farming systems in Cambodia

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ABSTRACT
Climate change poses a major threat to the livelihoods of rural smallholder farmers in Cambodia. Adaptation measures through sustainable land management (SLM) and farming practices can help farmers to increase their resilience to climate change and secure their livelihoods. This paper presents a novel approach for promoting landscape-specific integrated farming systems (IFS) through multi-stakeholder engagement, knowledge-based decision-making and improved land use planning. It presents a stepwise participatory approach, applied under an IFAD-funded project, to define context-specific IFS models. Through co-production processes with multiple stakeholders, three landscape units and seven landscape-specific IFS models consisting of different SLM technologies were defined and demonstrated on 1,500 farms in two case study sites. The process included training and awareness raising to enhance local stakeholder engagement in developing integrated farm plans. This paper provides insights into how such a novel approach can be embedded in rural development projects to enhance smallholders' resilience and livelihoods.

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KEYWORDS
Integrated farming systems; climate resilience; landscape approach; stakeholder engagement; Cambodia

Introduction

Southeast Asia is among the regions strongest hit by climate change impacts, with alarming trends for more intense rainfall and associated flooding, more intense droughts, and an increase in pests (IPCC, 2021, 2022). Such changes result in compound risks to food systems, human and ecosystem health, livelihoods, and infrastructure (IPCC, 2019). Smallholder farms with less than 2 ha dominate agricultural production in Cambodia and contribute significantly to food production, ecosystem health, and rural livelihoods (Graeub et al., 2016; Ricciardi et al., 2018). These smallholder farmers are particularly affected by the consequences of the impacts of climate change and their livelihoods are at risk, and farmers are in need of advanced knowledge for climate-resilient farming. Making agricultural systems more climate resilient calls for context-specific knowledge and more sustainable development pathways in the agricultural sector (Colloff et al., 2021; Giller et al., 2021). In addition to the impacts of climate change, these farms are affected by unsustainable land use and fast agrarian transformation. Land use is changing rapidly – but current trends of forest-clearing for agriculture

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and increasing environmental degradation are neither climate friendly nor climate change resilient (Ingalls et al., 2018; Kong et al., 2019). Sustainable land use and farming practices increasing the diversity and agrobiodiversity of the farming systems are therefore crucial to support farmers in increasing their climate resilience and securing their livelihoods (Rist et al., 2020; van Zonneveld et al., 2020).

Farming systems are embedded in landscapes with specific agro-ecological settings, economic opportunities (and limitations), institutional settings, and cultural values (Darnhofer et al., 2012). Therefore, planning for climate-resilient farming systems must be embedded into the wider landscape and should not take place in isolation (Reed et al., 2020, 2021; Zanzanaini et al., 2017). Approaches that integrate objectives at the landscape scale have gained increasing support in the contemporary conservation and development discourses (Sayer et al., 2013) and feature prominently in global policy debates and conventions for climate, food security, biodiversity, and sustainable development at large (Reed et al., 2021).

Within the farming landscape discourse, the concept of integrated farming system (IFS) has emerged as a promising option. While farmers try to combine different farming practices on their farm, the term of IFS was introduced by the project to pay particular attention to advance synergies and benefits between different practices on the farm and to make them visible and attractive to farmers. IFS evolved with the aim to combine multiple crops (e.g. cereals, legumes, tree crops and vegetables) and multiple enterprises (e.g. livestock, apiary and aquaculture) on a single farm in an integrated manner (Behera, 2015). An IFS may feature several sustainable land management (SLM) technologies, related to soil conservation and fertility management, or improved water use efficiency through water harvesting. SLM is defined as the sustainable use of land resources – including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and ensuring their environmental functions (WOCAT, 2007). IFS apply ecological principles and have proven to be advantageous for building climate resilient farms, while improving agricultural productivity and farm income (Behera & France, 2016). Such sustainably managed land ensures ecosystem function, delivering goods and services with multiple biophysical and socio-economic benefits, as well as increased resilience to the challenges of climate change and other natural hazards (Harari et al., 2017).

In Cambodia, IFS identified so far include agro-silvo-aqua-pastoral systems with a synergetic circular relationship, in which by-products (e.g. waste) and environmental improvements (e.g. micro-climate) from one system benefit another. IFS is implemented in Cambodia in some areas but should be further strengthened, evaluated, and promoted in view of the upcoming challenges related to the impact of climate change and other related issues, as well as the impact of pandemics (Dixon et al., 2021).

Over the last decades various efforts have been made to document existing knowledge related to sustainable land management (SLM) in various agroecological zones in Cambodia, as well as at the regional and global levels. WOCAT developed a methodology to compile fragmented knowledge about SLM into a readily available global database (WOCAT, n.d.; WOCAT DB, n.d.). WOCAT captures the diversity of single practices as well as their combination towards IFS (Liniger et al., 2019). Furthermore, the regional platform on agroecology for South-East Asia provides information on agroecological systems and related SLM practices (ALiSEA, n.d.). However, this knowledge relevant for a broad range of local actors, specifically smallholder farmers in Cambodia, has not been sufficiently compiled and used for uptake (Liniger et al., 2017). Further, there is a lack of understanding of the systemic perspective of farming systems embedded in landscapes, and the derivation of climate-resilient farm plans.

Therefore, readily available tools and approaches are needed for guiding smallholder farmers, extension workers, and local actors through the required steps to develop climate-resilient farm plans. Collaborating with smallholder farmers and other local stakeholders is considered a precondition for successful SLM (Schwilch et al., 2012). Incorporating local stakeholders in the design and monitoring processes of SLM projects and programmes increases empowerment, ownership, and engagement and is therefore considered fundamental to ensure sustainable development pathways in the agricultural sector (Reed et al., 2021). As stated by Pohl et al. (2021) co-production of knowledge and transdisciplinary research can be considered as equivalent terms for purpose-driven collaborative processes of knowledge production among researchers of different disciplines, inter- and trans-disciplinary fields, and representatives of private and public sectors including civil society. Many studies emphasise that transdisciplinary research is crucial to address sustainability challenges as it brings together diverse societal actors and their perspectives, knowledge, and forms of expertise (Chambers et al., 2022; Pohl et al., 2021; Sarmiento Barletti et al., 2020).

The overall objective of this paper is to present a novel stepwise, participatory, and gender-sensitive approach promoting landscape-specific integrated farming systems (IFS) to improve farm resilience to climate change and smallholder livelihoods. The specific objectives following a step-by-step approach are to (1) identify relevant landscapes for specific SLM interventions by smallholder farmers, (2) identify SLM technologies, their impacts and climate resilience, and synergies between them, (3) raise awareness on SLM/IFS at national, provincial and local level, and (4) design farm plans and consolidate IFS models. The approach was developed in IFAD's Scaling-up Climate Resilient Agriculture (SUCRA) project, aiming to improve livelihood and the resilience to climate extremes on 1,500 farms in the provinces of Kampong Chhnang and Pursat. The present research arose from the interest by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Cambodia to develop a practical methodology to foster SLM upscaling through IFS.

Materials and methods

Study sites

The activities presented in this paper were conducted in the context of the SUCRA project (2018–2022). The project focused on smallholder subsistence farms in remote rural areas that are considered less favourable due to their food and nutritional insecurity, limited market access, and their climate vulnerability. The project selected one district in Kampong Chhnang (KPC) province and one district in Pursat (PST) province in central southern and central western Cambodia (Figure 1). Situated in the monsoonal tropics, with a distinct wet (May–October) and dry season (November–April), these provinces have an average annual temperature of 28.5°C (average max. of 31°C in April, average min. of 26°C in December). The average annual rainfall is 1,261 mm with an average monthly maximum of 220 mm in September and a monthly minimum of less than 30 mm between December and February (RIMES & UNDP, 2020).

In KPC province, 12 villages were selected in two communes in Sameakii Meanchey (SMC) district, characterised by uplands (above floodable zones/floodplains) with sandy soils and lowland floodable areas. The SMC has a total area of 672.1 km^2, with a total population of slightly more than 80,000 based on the 2019 national census. In PST province the study was conducted in 11 lowland villages in two communes of Talou Saenchey (TSC) district. The district has a total area of 461.3 km^2 with a total population of 31,358 in 2019 (City Population, n.d.). The main occupation of the residents in both districts is agriculture, especially rice cultivation. Remittances from migrant workers are an important secondary source of income.

Methodological framework

A novel approach to promote landscape-specific IFS to help smallholder farmers in rural areas to develop climate-resilient farms and improve their livelihoods was elaborated by the SUCRA project. The methodological framework consists of five objectives and builds on previously developed participatory and community-based methods for the planning and implementation of sustainable

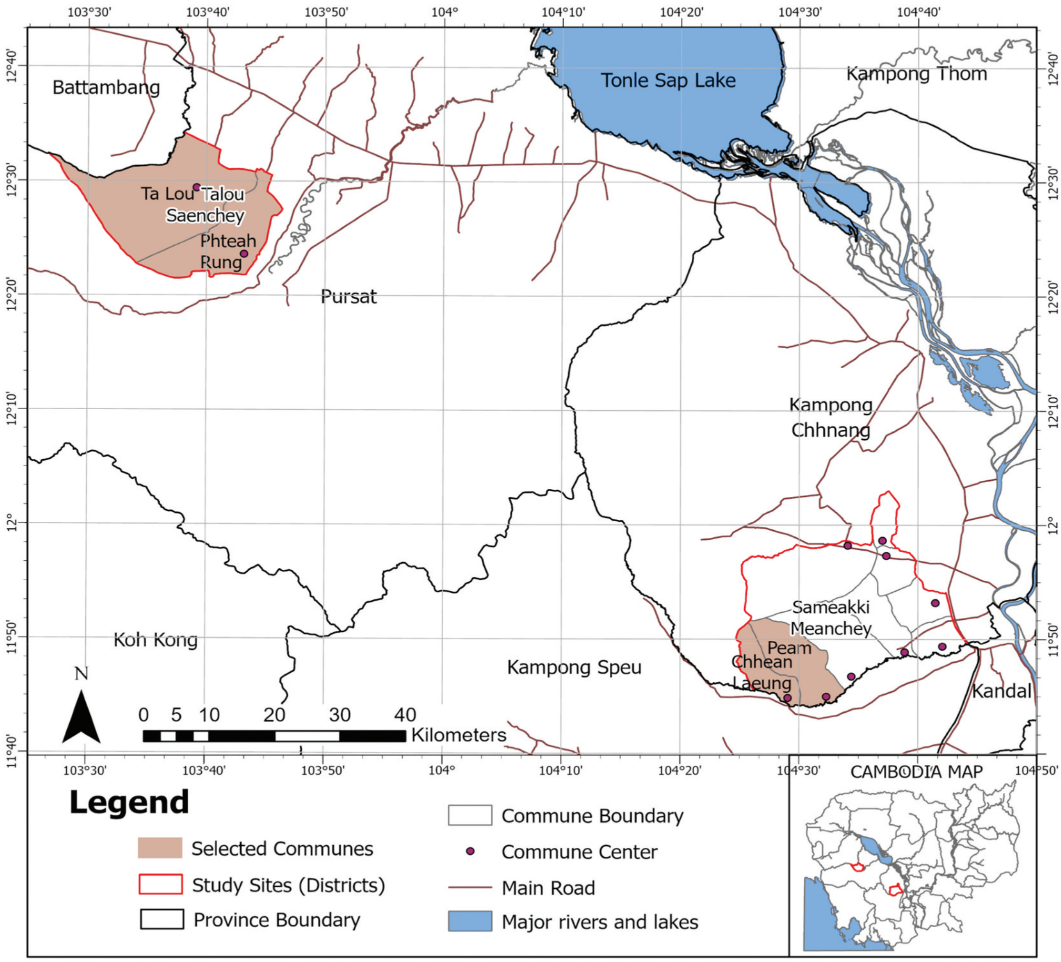


Figure 1. Map showing locations of the study sites in Pursat and Kampong Chhnang provinces.

land management (Figure 2 and Table 1). It includes stakeholder learning and knowledge-based decision support systems, as well as a systemic landscape perspective (WOCAT questionnaires and database (Liniger et al., 2019; Reed et al., 2021; Schwilch et al., 2012; WOCAT, n.d.)).

Objective 1: identify landscapes for interventions

A detailed characterization of the agricultural landscape was done in the selected study sites. The 'general landscape units' were defined in a multi-stakeholder set-up through expert consultations, joint field visits and reflection processes involving all the relevant project partners (Table 1, Objective 1). The landscape delineation was based on biophysical (agro-ecological zones (AEZ), slope, and groundwater table) and social criteria (human settlement and labour availability). Various available knowledge bases were consulted such as Google Earth maps/digital terrain model, drone pictures, and information about AEZ.

Objective 2: identify SLM technologies, their impacts and climate resilience, and synergies between them

We identified and analysed existing sustainable land management (SLM) technologies practiced on the project farms and on other farms in the selected provinces. This was done through a mixed-

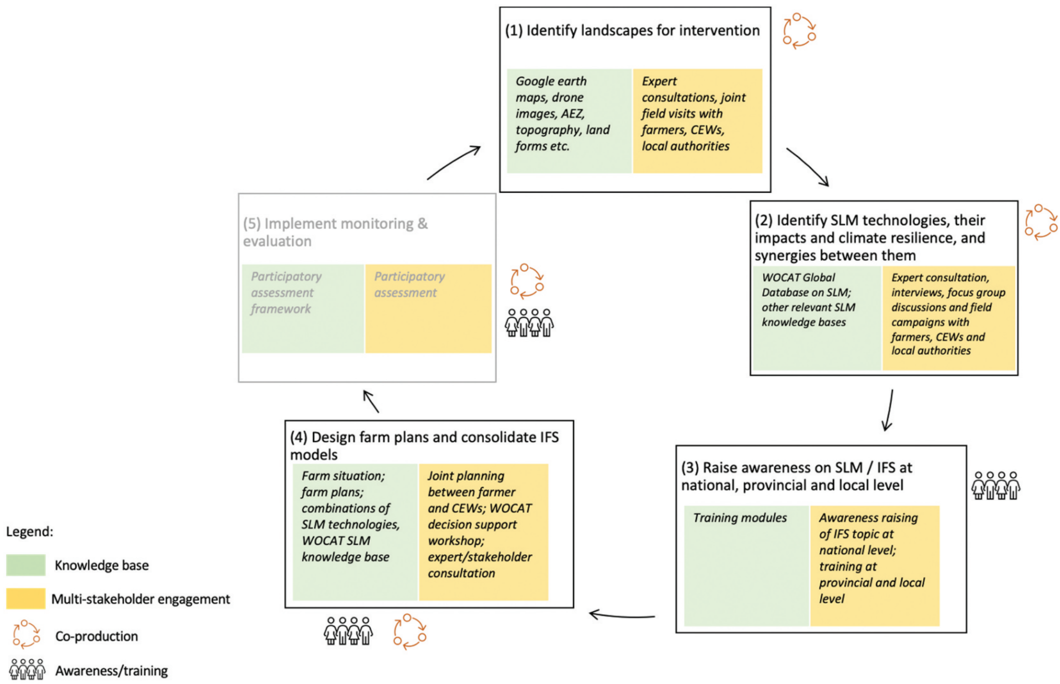


Figure 2. Methodological framework of the IFS approach for the co-production of IFS models and farm plans. (Objective 5 is not part of this paper). Note: CEW: Community Extension Workers.

methods approach, building on field campaigns, interviews and focus group discussion with smallholder farmers, commune extension workers (CEWs), Provincial Departments of Agriculture, Forestry and Fisheries (PDAFF), and local authorities. We consulted available documentation, the WOCAT documentation of SLM Technologies in Cambodia (WOCAT DB, n.d.), guidelines and resources by the MAFF (ASPIRE, 2018), IIRR success stories (IIRR, n.d.), and other sources. Synergies between SLM technologies were discussed, highlighting the substantial benefits of such combinations.

Objective 3: raise awareness on SLM/IFS at national, provincial, and local level

The importance of promoting landscape-specific solutions, the impacts of single technologies and synergies between them, and potentials for combinations into IFS were discussed at national, provincial, and local levels (Table 1: objective 3). For this a national kick-off workshop was organised at the beginning of the project attended by 60 people from government and non-governmental organisations. Furthermore, materials and modules were developed for a training of trainers (TOT) and a training of farmers (TOF). The latter included farmer field days and exchange events at the local level organised by researchers of the Royal University of Agriculture (RUA) and experts of the International Institute of Rural Reconstruction (IIRR).

Objective 4: design farm plans and consolidate IFS models

Farm plans were jointly developed between farmers and CEWs by considering the following aspects: farm size, labour availability on the farm, food and nutritional security, and preferred crops. The main objective was to increase climate-resilience and farm productivity to meet farmers own food needs and to sell potential production surpluses on the local market. The farm plans were developed in consideration of the General Landscape Unit (GLU) through a joint learning and reflection process by combining SLM technologies into Integrated Farming Systems (IFS) (Table 1, Objective 4a). The farm plans were reassessed and improved with the WOCAT Decision Support method, through

Table 1. A methodological framework for the co-production and implementation of IFS models in view of improved climate resilience and smallholder livelihood.

Objectives	Scale	Multi-stakeholder engagement	Knowledge base	Co-production method	Results
(1) Identify landscapes for intervention	District Village Farm	- Expert consultations between RUA, IIRR, PDAFF, local authorities - Joint field visit with farmers, CEWs, local authorities (commune, village leaders)	- Google earth maps/ digital terrain model - Drone pictures of the farm/ landscape - Agro-ecological zones (AEZ) for Cambodia (MoAFF)	- Joint reflection (online and during field visits) - Exchange and mutual learning during on-site workshop	- General landscape units identified and defined
(2) Identify SLM technologies, their impacts and climate resilience, and synergies between them	District Village Farm Farm field	- Interviews (simplified questionnaire), focus group discussions and field campaigns together with farmers/land users, CEWs - Expert consultation (between RUA, IIRR, PDAFF)	- WOCAT Global Database on SLM (https://qcat.wocat.net/en/wocat/) - Other relevant SLM knowledge bases (e.g. MAFF guidelines, IIRR success stories)	- Joint reflection and learning process during field visits - Search for and joint evaluation of documented SLM practices - Exchange and mutual learning	- Existing SLM technologies identified and analysed regarding their impacts and climate resilience - SLM technologies clustered into SLM technology groups - Synergies between SLM technologies identified
(3) Raise awareness on SLM/IFS at national, provincial, and local level	National Provincial Local	- National multi-stakeholder workshop (in Phnom Penh) - Expert consultation (between RUA, IIRR, PDAFF) - Training at provincial and local level	- Developed training modules	- Exchange and mutual learning during trainings, field visits, workshops and meetings	- General awareness raised on the combinations of SLM technologies and concept of IFS - PDAFF officials, CEWs and farmers trained on the concept of IFS at provincial and local level
(4a) Design farm plans and IFS models	Farm Farm field	- Joint planning and decision support stakeholder workshop with farmers and CEW to improve the farm plan (Schwilch et al., 2012) - Joint implementation by farmer household	- Farm situation - Recommendations of promising combinations of SLM technologies - WOCAT SLM knowledge base	- Joint learning process and reflection process during field visits and on specific farms - Exchange and mutual learning	- Farm plans developed and implementation started
(4b) Consolidate IFS models	Farm Farm field	- Expert/stakeholder meeting between RUA, IIRR and WOCAT	- Developed farm plans - Result of the decision support workshop	- Joint reflection process during online workshops - Exchange and mutual learning	– 7 IFS Models
(5) Implement monitoring & evaluation	Farm Farm field	- Participatory farm assessment	- Participatory assessment framework (H. Liniger et al., 2022 unpublished)	- Joint reflection and learning process during the development of the methodology and testing in the field	- Participatory assessment of implemented farm plans (ongoing, unpublished)

*: Note: the 5th objective is not part of this paper.

a stakeholder workshop (Bachmann et al., 2018). Through an expert consultation between universities, extension and project staff, the 1500 farm plans were consolidated into context-specific IFS models for the respective landscape units. The IFS models identify and propose production system improvements to enhance farm productivity, climate-resilience, and sustainability (Table 1, Objective 4b).

Objective 5: implement monitoring & evaluation

The IFS implementation was monitored and evaluated through a participatory approach (Table 1, Objective 5), and a participatory assessment framework was developed and implemented (Liniger et al., 2022). The monitoring process is not part of this paper.

The methodological framework describing the approach builds on a transdisciplinary research and knowledge co-production approach that brings together diverse societal actors and their perspectives, knowledge, and forms of expertise (Lang et al., 2012; Pohl et al., 2021). The Royal University of Agriculture (RUA) was leading the project involving the International Institute of Rural Reconstruction (IIRR) as the main implementing partner in the provinces in collaboration with the Provincial Departments of Agriculture, Forestry and Fisheries (PDAFF), commune extension workers (CEWs) working under PDAFF, smallholder farmers, and local authorities (commune, village leaders), and the Centre for Development and Environment (CDE) as a backstopping partner.

Results

General landscape units

Expert consultations revealed that there are three general landscape units (GLUs) in the two districts, *Homestead*, *Homestead with Rice*, and *Chamkar* (Table 2 and Figure 3). GLUs reflect key biophysical and social criteria of the landscapes. The same GLU can be used in the two project areas due to similar geographic and landscape characteristics (upland and lowland areas).

The Homestead GLU is characterised as an area of land in the lowland, a slightly elevated zone above floodable land with flat or gentle slope (<5%). It is a residential place that contains a permanent house occupying a portion of the land and is usually located in villages or along rural access roads. It has potential for IFS implementation due to proximity to water sources (either through tap, drilled well, pond or canal), availability of plots for cultivation and livestock production, and availability of labour due to permanent settlement. The average size is 0.52 ha (min. 0.03 ha, max. 5.7 ha). The farms have been established more than 30 years ago.

The Homestead with Rice GLU is located mainly in the lowland with a slope of less than 3%. It has the common features of the *Homestead* GLU, such as a permanent residential house, easy access to water/groundwater, available plots for cultivation, and available labour, with the addition of a paddy field adjacent to the homestead compound at a lower area. The paddy field is cultivated with medium-term rice varieties with a growing period of 4–5 months during the wet seasons (wet-season rice) due to water availability for irrigation. The average size of this GLU belonging to a household is 0.78 ha (min. 0.07 ha, max. 8.0 ha). The farms have been established more than 30 years ago.

Chamkar is a Khmer (Cambodia's national language) term meaning 'farm' and generally refers to cultivated land in the upland, on an elevated newly settled area (less than 5–20 years), where secondary forest has been converted to farmland. It is mostly rainfed or with restricted irrigation potential, and without a permanent residential house. The *Chamkar* GLU occurs on a plateau or an area of gentle to steep slopes that are susceptible to erosion. Farmers mostly grow commercial crops (MAFF, 2021) such as mung bean, peanut, cassava and sweet corn. Some cases with larger orchards also have citrus, longan, mango and lemon trees. The average size of this GLU is 0.67 ha (min. 0.04 ha, max. 7.5 ha).

Table 2. Characteristics of General Landscape Units defined for IFS implementation.

	General Landscape Units (GLUs)		
Key biophysical and social criteria	HOMESTEAD	HOMESTEAD WITH RICE	CHAMKAR
Agro-Ecological Zone	Lowland/flood plains; Upland above floodplains	Lowland/flood plains	Mostly upland
Slope	Flat (0–2%)	Flat (0–2%)	Gentle, moderate to rolling (<15%)
Groundwater table	Shallow (<1m) to medium (<5m)	Shallow (<1m) to medium (<5m)	Very deep (>10m) to inaccessible (>50m)
Settlement history	Settled >30 years ago	Settled >30 years ago	Newly settled/cleared land/forest
Residential house	Yes	Yes	No
Average farm size [ha]	0.52	0.78	0.67
Labour availability (family/casual workers)	Medium to high	Medium to high	Low

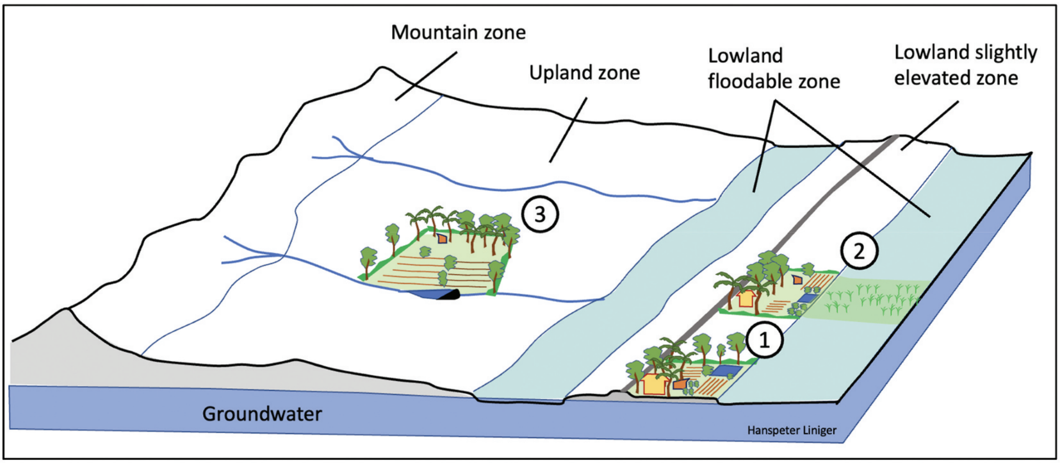


Figure 3. Simplified illustration of the identified General Landscape Units for IFS implementation. 1: Homestead (GLU1), 2: Homestead with Rice (GLU2), 3: Chamkar (GLU3).

The three GLUs have different biophysical conditions, especially regarding access to water, topography, and slope. The shorter period of human settlement affects the development of infrastructure and farmer communities. Unlike the first two GLUs, which are in flat areas with good access to groundwater, and more developed with denser settlements, this GLU has less favourable access to water on sloppy land recently cleared from secondary forest, due to the recent immigration and settlement of farmers that are now faced with a new natural and human environment (Ingalls et al., 2018).

SLM technologies, their impacts and climate resilience, and synergies between them

The socio-economic, socio-cultural, and ecological impacts and climate resilience of 22 SLM technologies documented by SLM practitioners and experts in the WOCAT Global Database and practiced in the concerned provinces in Cambodia were assessed. The technologies can be divided into four groups, namely (i) agroforestry, (ii) rotational systems, (iii) integrated soil fertility management and (iv) water management (WOCAT, 2016) (Table 3). All technology groups focus on improving production and ensuring ecosystem function and services. The produced products are primarily for home consumption, and the surplus for sale on the local market.

Table 3. SLM technology groups/SLM technologies and their impacts and climate resilience (coping) after implementation.

	Socio-economic impacts[3]					Socio-cultural impacts		Ecological impacts					Climate resilience (coping of natural system with climate extremes)[4]					
Main SLM Technology groups[1]/SLM Technologies (Reference code)[2]	Crop production	Risk of production failure (decreased)	Product diversity	Farm income	Work load (decreased)	Food security/ self-sufficiency	Health situation	Soil moisture	Soil cover	Soil organic matter	Beneficial species (e.g. polinators)	Micro-climate	Drought	Flood	Tropical storms	Average impacts	Average resilience	Average impacts and resilience
Agroforestry																		
Intercropping of peanut between cashew nut trees in upland areas (T2315)	2	2	2	2	−1	2	1	1	3	1	2	3	2	2	na	**1.7**	**2.3**	**2.0**
Intercropping of orange trees with mungbean in mountainous areas (T3146)	2	2	2	3	0	3	2	2	2	3	2	na	2	2	na	**2.1**	**2.0**	**2.0**
Eggplant cultivation technique between lemon trees (T3153)	2	2	2	2	1	2	2	2	2	2	2	2	3	1	na	**1.9**	**2.0**	**2.0**
Intercropping of eggplants between mango trees with rice straw mulching (T2255)	2	3	na	2	−2	2	2	2	2	2	2	3	3	1	1	**1.8**	**2.0**	**1.9**
Improved orchard with an integrated farming system (T2263)	2	2	2	2	2	2	3	2	2	2	na	na	2	2	1	**2.1**	**1.7**	**1.9**
Home garden (pomelo, lemon, supplementary crops) (T2099)	2	2	1	2	2	2	3	1	na	2	2	3	2	1	1	**2.0**	**1.8**	**1.9**
Intercropping of pineapple between orange and mango trees (T2843)	−1	1	2	2	1	na	3	1	1	2	2	2	2	1	na	**1.5**	**1.7**	**1.6**
Rotational systems																		
Crop diversification with the application of rotation techniques (T3145)	2	2	2	2	−2	2	2	2	na	2	2	2	3	3	na	**1.6**	**2.7**	**2.2**
Sandy soil improvement by using natural fertilizer and liquid compost (T2949)	2	2	2	2	2	3	3	2	3	2	2	na	na	na	na	**2.3**	*na*	2.3

(*Continued*)

Table 3. (Continued).

Main SLM Technology groups[1]/SLM Technologies (Reference code)[2]	Socio-economic impacts[3]					Socio-cultural impacts		Ecological impacts					Climate resilience (coping of natural system with climate extremes)[4]					
	Crop production	Risk of production failure (decreased)	Product diversity	Farm income	Work load (decreased)	Food security/ self-sufficiency	Health situation	Soil moisture	Soil cover	Soil organic matter	Beneficial species (e.g. polinators)	Micro-climate	Drought	Flood	Tropical storms	Average impacts	Average resilience	Average impacts and resilience
Crop rotation to promote safe vegetables (T3165)	1	1	2	2	na	3	2	na	2	na	2	na	na	na	na	1.9	*na*	*1.9*
Intercropping of vegetables between orange trees (T3173)	3	na	na	na	−2	2	na	3	2	na	1	na	na	na	na	*1.5*	*na*	*1.5*
Integrated soil fertility management (including organic farming)																		
Cultivation of organic vegetables to improve the household economy and the soil quality (T3151)	2	2	2	3	3	3	na	na	na	3	3	na	2	2	na	2.6	**2.0**	**2.3**
Using slurry from biodigester for soil improvement (T2137)	3	2	2	3	2	3	2	1	2	2	2	na	2	na	na	**2.2**	*2.0*	**2.1**
Using dry compost on paddy rice fields (T3215)	3	2	na	2	−1	2	2	2	na	2	na	na	na	na	na	**1.8**	*na*	**1.8**
Intercropping of mung bean and banana in the uplands (T1890)	2	1	1	2	na	2	na	2	2	1	2	na	na	na	na	**1.7**	*na*	1.7
Mulching with water hyacinth (Eichhornia crassipes) after the monsoon floods (T1223)	3	na	3	na	−3	na	na	3	3	3	na	na	2	−1	2	*2.0*	**1.0**	1.5
Production and use of rice husk biochar in rice seed beds and vegetable production (T1229)	3	na	na	na	−2	3	2	1	na	2	na	1	2	−1	na	*1.4*	0.7	*1.0*
Water management: Irrigation/Water harvesting/Water use efficiency/Aquaculture																		

(*Continued*)

Table 3. (Continued).

Main SLM Technology groups[1]/SLM Technologies (Reference code)[2]	Socio-economic impacts[3]					Socio-cultural impacts		Ecological impacts					Climate resilience (coping of natural system with climate extremes)[4]					
	Crop production	Risk of production failure (decreased)	Product diversity	Farm income	Work load (decreased)	Food security/ self-sufficiency	Health situation	Soil moisture	Soil cover	Soil organic matter	Beneficial species (e.g. polinators)	Micro-climate	Drought	Flood	Tropical storms	Average impacts	Average resilience	Average impacts and resilience
Crop rotation between mango trees in combination with drip irrigation (T2236)	2	2	2	3	3	2	2	2	2	na	2	2	2	2	1	**2.2**	**1.8**	**2.0**
Coconut leaves mulching for winter melon cultivation (T3152)	2	na	na	2	1	2	2	3	3	2	2	na	2	1	1	**2.1**	**1.3**	**1.7**
Growing corn using drip irrigation system (T3144)	2	2	na	2	2	2	2	2	na	2	na	na	3	na	na	2.0	*3.0*	2.5
Use of solar water pumping to adapt to climate change (T3214)	2	na	na	2	3	na	na	na	na	na	na	na	3	na	na	*2.3*	*3.0*	*2.7*
On-farm ponds to alleviate the potential impact of seasonal droughts and for increasing crop cultivation and aquaculture (T2844)	2	2	2	3	na	na	na	2	2	na	na	na	2	na	na	*2.2*	*2.0*	*2.1*

[1]WOCAT Technology Questionnaire 2018 (p. 17, SLM Technology groups); [2]Reference: WOCAT Technology database: https://qcat.wocat.net/en/wocat/; [3]Impact score: (3: very positive; 2: positive; 1: slightly positive; 0: negligible impact; −1: slightly negative; −2: negative; −3: very negative; na: not available; Reference: WOCAT QT questionnaire); [4]Coping score: (3: very well; 2: well; 1: moderately; −1: poorly, −2: very poorly; na: not available; Reference: WOCAT QT questionnaire)

The scoring of the impacts of SLM technologies from the WOCAT Global Database showed that all groups score mostly high in terms of socio-economic, socio-cultural, and ecological impacts. However, some technologies are very demanding at the implementation stage and therefore score rather negatively in terms of workload. This must be taken into account when planning interventions, particularly in view of possible gender-specific impacts. Further, the climate resilience of the single technologies and technology groups was assessed. More than three-quarters of the technologies contain information on coping with droughts: 30% cope 'very well' and 70% cope 'well'. The documentations of 60% of the technologies contain information on coping with floods: almost half cope 'very well' to 'well', 38% cope 'moderately' and 15% cope 'poorly'. Only one-quarter of the technology provides information on coping with tropical storms. Scores are mostly 'moderately' to 'well'.

Soil/vegetation cover is a key pillar in all four groups. The agroforestry group combines high-value tree products (nut trees (cashew), orange, mango, lemon) with high-value and nitrogen-fixing undergrowth (e.g. mung bean), high-value crops (e.g. eggplants) and ground fruits (pine-apple). Due to increased cover and multi-storey cropping, the agroforestry group copes from 'well' to 'very well' with drought as the microclimate is improved and 'well' to 'moderately' with floods. The other three groups (rotational systems, integrated soil fertility management, water management) have their priority on the production improvement through better soil fertility, plant diversification, and irrigation.

The SLM technologies/groups were assessed regarding the benefits and products they are providing to other SLM technologies implemented on the same farm, leading to promising combinations and synergies. Although not yet documented in the WOCAT database for Cambodia, two livestock groups (small and large livestock) were added after interactions with different stakeholders during workshops, trainings and fieldwork. It became evident that they have an importance for future development of IFS models and thus needed to be included in further analysis. The identified synergies between the SLM technologies providing or reducing inputs needed by other SLM technologies on the same farm are listed in Table 4. This reduces costs for external inputs and makes farmers less dependent. Benefits/products are divided into nutrients, feed/fodder, water, and micro-climate. Based on field interviews and Focus Group Discussions (FGD) with farmers and local facilitators, two additional SLM groups, small and large livestock production, showed the vital importance of the livestock component for an integrated farm system. They have been included for the assessment of benefits and products of the different technologies within an IFS they can provide to each other (Table 4).

Improved productivity through agroforestry, rotational systems, integrated soil fertility management combined with better water management and use of by-products (feed/fodder, biomass, residues and organic waste) in other technologies are key assets for combining different technologies into one production system. Key for achieving this is improved water management by reducing water losses through evaporation (through windbreak, shade and mulching) generating a favourable micro-climate and setting up complementary irrigation systems. Key points of the two added livestock groups are their added value for fertility management. On one side producing nutrients for other technology groups in the form of manure, on the other side receiving feed/fodder/residues from other SLM technologies.

SLM and IFS awareness at national, provincial, and local level

Stakeholder consultations revealed a major gap at national, provincial, and local levels in terms of understanding the importance and benefits of IFS. This gap was addressed through capacity-building events at all levels: At the national level, a kick-off workshop facilitated the discussion on promoting IFS practices in various farming landscapes with different pre-conditions, e.g. availability of water. It included the sharing of various experiences, lessons learned, opportunities and concerns by the diverse participants. At the provincial level, key actors including commune extension workers

Table 4. Benefits and products from different SLM technology groups providing inputs or reducing inputs *(in italics)* to other/neighbouring SLM technology groups.

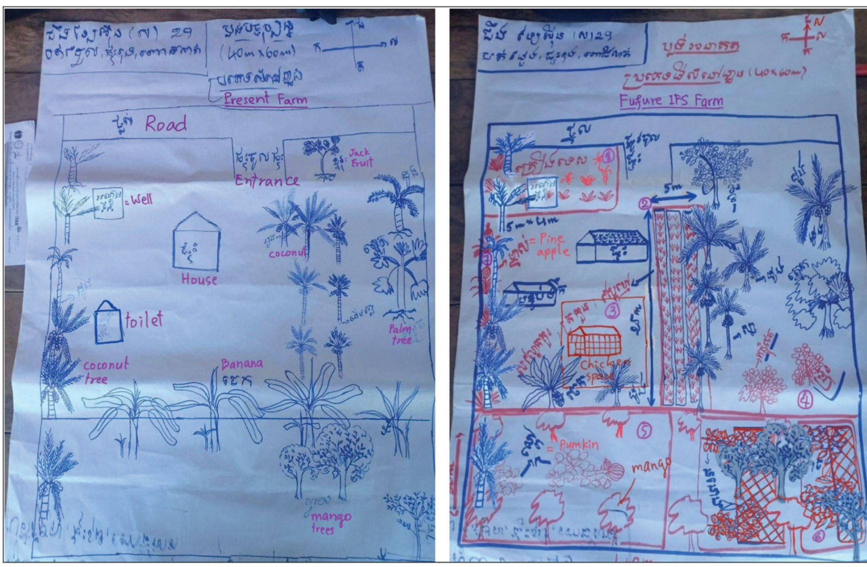
SLM Ts groups (TG)	Nutrients	Feed/fodder	Water	Micro-climate
Agroforestry (TG1)	- *Reduced demand for manure/fertilizer* - Biomass and residues for fertility enhancement	- Enhanced biomass and residue production	- Reduced water loss by evaporation through a better micro-climate - *Decreased water demand due to improved water use efficiency*	- Windbreak and shade, also reduced heating up of the soil surface and air temperature, for neighbouring SLM technologies
Rotational systems (TG2)	- *Reduced demand for manure/fertilizer* - Biomass and residues for fertility enhancement	- Enhanced biomass and residue production	- *Decreased water demand due to improved water use efficiency*	- Reduced heating up of soil surface and air temperature affecting neighbouring SLM technologies
Integrated soil fertility management (TG3)	- *Reduced demand for manure/fertilizer* - Provide additional nutrients/fertility	- Enhanced biomass and residue production	- *Decreased water demand due to improved water use efficiency*	- Reduced heating up of soil surface and air temperature affecting neighbouring SLM technologies
Water management (TG4)	- Production of additional nutrients, e.g. in fishponds	- Enhanced biomass and residue production	- Increased water use efficiency, making more water available for other SLM technologies leading to less competition	- Reduced heating up of soil surface and air temperature affecting neighbouring SLM technologies
Small livestock production (TG5)	- Manure	- Reduced organic waste and by-products from other LM practices	-	-
Large livestock production (TG6)	- Manure - Raw material for biodigester	- Reduced organic waste and by-products from other LM practices	- Roof water harvesting from stables	-

CEWs were trained by IIRR local experts on various topics such as SLM principles, SLM technologies and their benefits, the potential of IFS models, farm planning and farm business plan development, and basic financial literacy. The systemic perspective within landscapes was a new approach for CEWs and PDAFF officials who were not yet properly familiar with the SLM principles and benefits within landscapes. At village level, farmers were capacitated by IIRR staff and CEWs on the basic concept of IFS and the combinations of SLM technologies, farm production planning and basic financial literacy. In total, 1,502 farmers (884 females) were trained in both provinces. The interaction between the different actors at all levels increased their awareness, understanding and knowledge of the potential of diversifying farming systems. It created a foundation for the development of individual farm plans and its implementation. At the local level, the different actors were able to assess the specific situation of their farms, to identify weaknesses in the farming systems and to address them through the combinations of various SLM technologies.

Designed IFS farm plans

For each of the 1500 farms, two farm sketches were drawn, one for the status quo and one for the future status of the farm. They were complemented by an activity plan indicating key activities, responsibilities, timeframes and agricultural inputs needed for developing the climate-resilient farm. Figure 4 illustrates an example of a developed farm plan in Bat Rumduol village in PST, representing the present farm on the left and the future IFS plan on the right. The present farm (2400 m^2) is a homestead with few scattered fruit trees (coconut, jack fruit and mango trees, and banana) and as well as water source. For the future, the plan illustrates the intention to keep all the existing fruit trees and to add several new elements (in red) to the present farm such as small livestock (20 chicken) and agroforestry with intensified vegetable production (later defined as IFS Model 1, Table 5).

Through the designing of farm plans farmers learned to assess their current farm as a whole farming system and to develop synergistic combinations of technologies to make their farm more resilient and productive.



On the future IFS farm new added elements (in red):
1: herbs and spices such lemon grass.
2: leafy vegetable like celery cabbage and morning glory in rotation with long bean and cucumber (125 m^2).
3: small livestock mainly chicken (100 m^2).
4: multipurpose trees such as moringa and white leadtree *(Leucaena leucocephala)*.
5: additional mango trees intercropped with pumpkin.
6: additional mango trees with fruits like winter melon, wax gourd, and luffa gourd.
7: row of pineapples along the left fences through to lower end of the farm.

Figure 4. Sketch of a farm plan for the implementation of IFS M1 – present status (left) and future IFS farm (right) (Source: SUCRA project with authors' minor editing and added translation).

Table 5. Consolidated IFS models, their major products, benefits and challenges *(in italics)* for different general landscape units.

Model	SLM Ts groups included	Major products	Major benefits/*challenges*
ALL IFS models	**Agroforestry**	Vegetables, fruit trees, multi-purpose crops	- Agroforestry (AF) and fruit/vegetable production provides additional income. - Agroforestry provides a favourable environment and living conditions around the homestead/farm. - AF provides biomass, residues, mulch material and feed/fodder for other practices. - AF practices help enhance the ecosystems and its biodiversity, and provides favourable micro-climate, reducing water losses, and impact of heat waves and heavy tropical storms. - *Initial investment in seedlings; initial investments take at least two years for pay back.*
ALL IFS models	**Water management**: improved irrigation: drip, sprinkler, wells, etc. (6 out of 7) and rainfed agriculture (1 out of 7)	Vegetables, fruit trees, multi-purpose crops	- Increased total production including number of crops/growing period. - Securing crop production during dry spells and droughts. - *Initial investment high* - *Secured access to water: reliable ground water aquifer or water harvesting and storage practices.*
GLU 1: HOMESTEAD			
M1: IFS including **small livestock** – agroforestry – fruit/ vegetable production	TG1, TG2, TG3, TG4, **TG5**	Vegetables, fruit trees, multi-purpose crops, and **small livestock**	- Agroforestry benefits/*challenges* (see above) - Small livestock gives women opportunity to generate additional income in a short period with little investment. - Small livestock feed on by-products of other systems/provide nutrients and reduce costs for external inputs.
M2: IFS including **large livestock** – agroforestry – fruit/ vegetable production	TG1, TG2, TG3, TG4, TG5, **TG6**	Vegetables, fruit trees, multi-purpose crops, and **large livestock and fodder**	- Agroforestry benefits/*challenges* (see above). - Animal waste of large livestock makes an important contribution to soil fertility improvement, crop production, and reduces costs for external inputs. - Large livestock gives men additional opportunities to increase income and work on the farm. - Selling of large livestock is an important contribution to income. - *Large livestock: high initial investment into infrastructure and animals.*
M3: IFS including **artificial pond and aquaculture** – agroforestry – fruit/ vegetable production – small/large livestock	TG1, TG2, TG3, **TG4**, TG5 and/or TG6	Vegetables, fruit trees, multi-purpose crops, small and/or large livestock and forage, and **artificial pond and aquaculture**	- Agroforestry benefits/*challenges* (see above) - Artificial pond and aquaculture provide (nutrient-rich) water for irrigation, fish/frog/duck for self-consumption/selling on market. - Fish/frog/duck raising gives men and women opportunities to increase HH income. - Improved micro-climate around the pond and provision of water during dry spells. - *Pond: high initial investment into infrastructure (including labour).*
GLU 2: HOMESTEAD WITH RICE			

(*Continued*)

Table 5. (Continued).

Model	SLM Ts groups included	Major products	Major benefits/*challenges*
M4: IFS including **paddy rice cultivation** – agroforestry – fruit/vegetable production	T1, T2, T3, **T4**, T5 and/or T6	M1, M2 and/or M3 and adjacent **paddy rice cultivation**	- Agroforestry benefits/*challenges* (see above). - Farmers can extend production on the paddy field with short-growing period or fallow crops (e.g. mung bean) during the dry season after the rice harvest. - Rice straw and large livestock droppings are important materials for making compost essential for soil fertility. - Ducks and large livestock graze harvested plots, get additional feed, and provide droppings (nutrients).
M5: IFS including **paddy rice-fish aquaculture** – agroforestry – fruit/vegetable production	T1, T2, T3, **T4**, T5 and/or T6	M1, M2 and/or M3 plus and **paddy rice-fish aquaculture**	- Agroforestry benefits (see above). - Paddy rice-fish aquaculture provides two products (rice and fish) with less external inputs due to the diversified-nutrient-cycling (fish feeds on insects, water plants, and small fish in the paddy; and rice absorbs nutrients released from fish). - The diverse production gives men and women additional opportunities to increase HH income. - Increased resilience due to improved micro-climate, diversified farm activities and healthy ecosystems.
GLU 3: CHAMKAR			
M6: IFS including **rainfed commercial crops** - agroforestry – fruit/vegetable production	**TG1**, **TG2, TG3**	**Rainfed commercial crop** cultivation integrating vegetables, fruit trees, multi-purpose crops	- Agroforestry benefits (see above) - Farmers benefit from commercial crops as the main products. - Crops benefit from the diversified crop production including intercropping, and repellent crop mixing (reducing pests and diseases).
M7: IFS including **irrigated commercial crops** -agroforestry – fruit/vegetable production	TG1, TG2, TG3, **TG4**	**Irrigated** (pond, drilled well or natural stream) **commercial crop** cultivation integrating vegetables, fruit trees, multi-purpose crops	- Agroforestry benefits (see above) - Farmers benefit from commercial crops as the main products. - Crops benefit from the diversified crop production including intercropping, and repellent crop mixing (reducing pests and diseases). - The availability of water source for irrigation help secure and diversify the crop production in time of drought, cultivating additional commercial crops in rotation.

Consolidated IFS models

Seven IFS models emerged as a result of expert consultations with RUA, IIRR and WOCAT, based on a review of the 1500 farm plans and their development processes: IFS M1 to M3 for Homestead (GLU 1), IFS M4 and M5 for Homestead with Rice (GLU 2), and IFS M6 and M7 for Chamkar (GLU 3) (Tables 5 and 6, Figure 5). Each model has a particular set of SLM technology groups with its major products and additional benefits and inputs to other SLM technologies (Table 5). Each IFS model has agroforestry practices as they provide a favourable micro-climate to the whole farm, protect against extreme events, and provide inputs to other SLM technologies. However, a major challenge is the initial investment for an agroforestry system and the time needed to recover the costs. All IFS models have a strong water management aspect. Six out of seven use improved irrigation management and one improved rainfed agriculture. All of them are targeting improved water use efficiency either through improved irrigation practices and/or through reduction of runoff and evaporation losses.

In the GLU 1 farms, in addition to the agroforestry component, both small livestock (IFS M1) and large livestock (IFS M2) provide manure, increase soil fertility for intensification and increase productivity of other technologies, and reduce costs for external inputs. While small livestock has low establishment costs, large livestock involves significant investment costs. IFS M3 integrates artificial ponds and aquaculture and vegetable production through improved soil fertility and irrigation management. The production of fish, frogs and ducks provides additional nutrients, whereas the by-products from other systems are used as feed for the fish, frogs, and ducks. However, initial investment especially for pond production is high.

In the GLU 2 farms, paddy rice cultivation (IFS M4) (including short-growing period or fallow crops) is practiced on larger farms (average 0.8 ha) than the 'homestead' farms (average 0.5 ha). Paddy rice production provides substantial residues/straw such as fodder, mulching or compost material for other practices. Additionally, if available small or large livestock provides fertilizer for the rice paddy (manure, droppings). Paddy rice-fish aquaculture practiced in IFS M5 provides nutrient cycling without additional external inputs.

In the GLU 3 farms, crops benefit from the diversified crop production, the exchange of nutrients, and the reduced pest and diseases. Farms with restricted access to irrigation water are focusing on water-efficient rainfed agriculture including agroforestry with shade and windbreak and mulching (IFS M6). Rainfed commercial crops are the main products. Farms with access to creeks, rivers, and sites suitable for water harvesting in small dams allow higher production of biomass to be used in other practices on the farm for commercial crop production (IFS M7).

Table 6 further illustrates key, additional and optional components/characteristics and combinations of these components for each of the 7 IFS Models. All models are complex with the highest degree in 'homestead with rice' IFS M4 and IFS M5. However, this complexity allows positive synergies and material flows between them.

Table 7 shows the number of farms applying IFS models in different landscape units. After information campaigns by the project, where different farming systems were discussed, farms were selected based on the interest of the farmers to apply IFS models and the assessment of the suitability of the farm condition for these IFS models. Out of 1500 selected IFS farmers 57% were represented by women assuring a gender balance and representation of women and their interests, concerns and priorities. Almost half of the farmers (45%) eventually committed themselves to apply IFS M1. The second highest was a homestead with large livestock (23%). Overall, 13% selected Chamkar rainfed commercial crops (IFS M6). All the other IFS models represent less than 10%.

Discussion

The primary aim of the developed IFS approach is to strengthen climate resilience of rural communities through landscape-specific integrated farming systems. Despite the rapid agrarian transformation in Cambodia, agricultural production is predominantly conducted at the smallholder level

Table 6. Characterisation of each Integrated Farming System (IFS) model with key components (orange), and additional (blue) and optional (grey) components.

Key components / characteristics	**HOMESTEAD**			**HOMESTEAD WITH RICE**		**CHAMKAR**	
	IFS M1	IFS M2	IFS M3	IFS M4	IFS M5	IFS M6	IFS M7
IFS Model including	Small livestock	Large livestock	Pond & aquaculture	Paddy rice cultivation	Paddy rice-fish-aquaculture	Rainfed commercial crops	Irrigated commercial crops
Mixed vegetables	blue	blue	blue	blue	blue	blue	blue
Multi-purpose crops/bushes/trees	blue	blue	blue	blue	blue	blue	blue
Leguminous crops	grey	grey	grey	blue	blue	blue	blue
Commercial crops				grey	grey	orange	orange
Fruit trees	blue	blue	blue	blue	blue	blue	blue
Small livestock	orange	blue	blue	blue	blue	grey	grey
Large livestock (>2)		orange	blue	blue	blue	grey	grey
Pond and fish culture			orange	grey	grey		
Paddy field				orange	blue		
Paddy field-fish aquaculture					orange		
Composting (fertilizer)	blue	blue	blue	blue	blue	grey	grey
Bio-digester (gas production for cooking and lighting)		grey	grey	grey	grey		
Water source: Pond/well/tap water	blue	blue	blue	blue	blue		orange
Irrigation (importance)	+++	+++	+++	+++ (dry season)	+++	Mostly rainfed	++
Colour legend:	*Key component* (orange)		*Additional component* (blue)		*Optional component* (grey)		

(Ingalls et al., 2018). In the last 15 years, migration from one rural area to another has increased very often from lowland to upland areas, as a response to rural poverty and landlessness (Diepart & Dupuis, 2014). This development has led to land pressure and a decline in the size of landholdings per household (Ingalls et al., 2018). It has also led to forest clearing of marginal, less suited land to develop agricultural land. Further, the impacts of climate change with increased extreme events put additional pressure on the farming systems (IPCC, 2022). To ensure that these farming landscapes are developed in a sustainable way, alternative climate-resilient farming models for smallholder farmers are crucial. These alternative farming models are central to promote sustainable land management at the farm level and to create livelihood opportunities. During the Covid pandemic, IFS farms became very attractive for returning migrants, who were looking for short-term jobs, and provided opportunities for farmers to stay in the area and prevented migration (preliminary results from the IFS survey, unpublished).

Strengthening climate resilience through IFS

The developed IFS approach takes the local biophysical and social conditions of the various land-scapes into account and reveals the importance of differentiating landscape types to find more

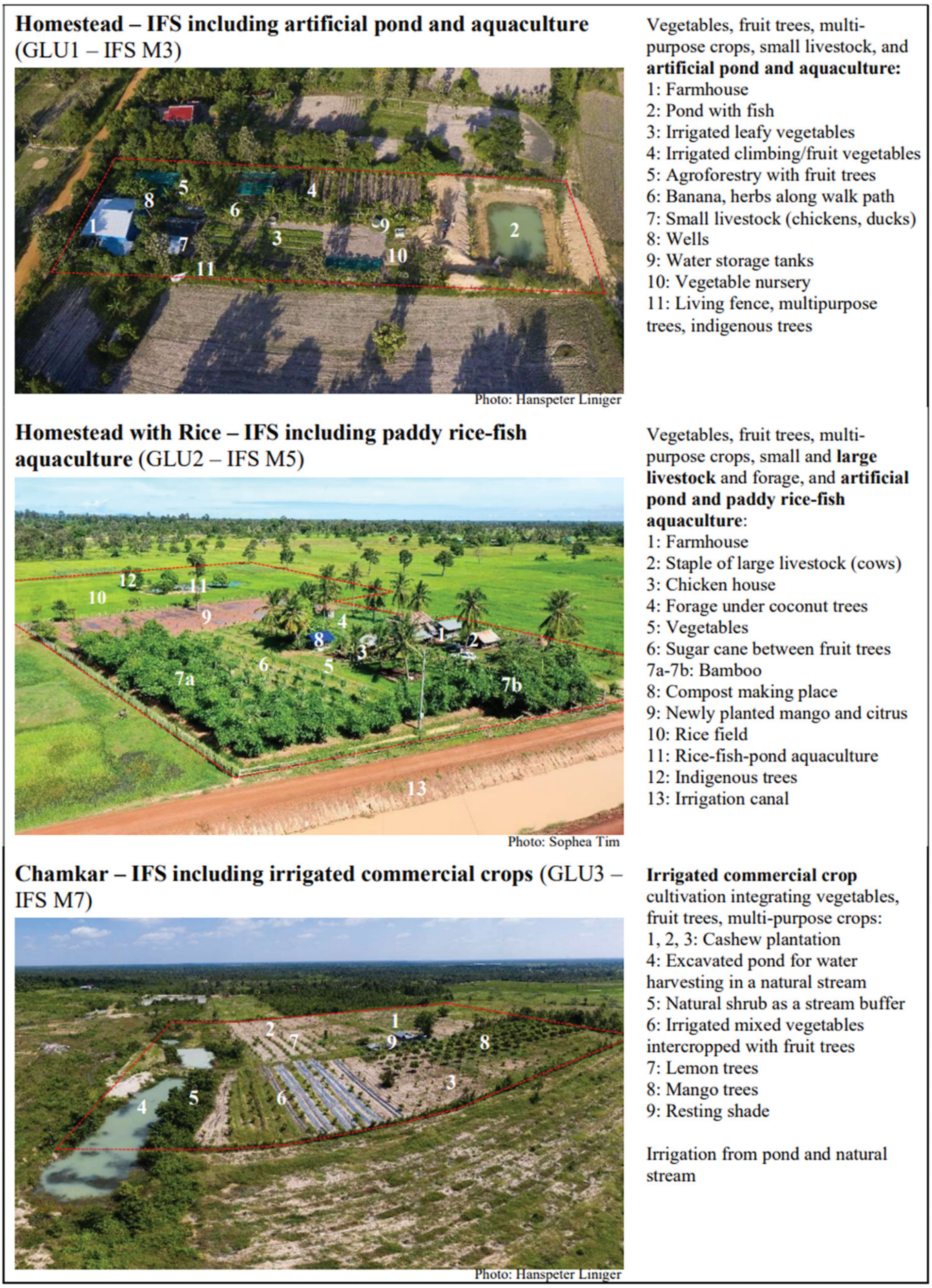


Figure 5. Illustration of Integrated Farming System (IFS) models for each General Landscape Unit (GLU).

suitable combinations of SLM technologies. Key variables for landscape differentiation are biophysical (agroecological zones (AEZ), slope, and groundwater table and social criteria (human settlement, enabling labour availability)). In the study area farmers have their land in blocs and their fields are not dispersed over large areas. This favours the development of IFS as different land management practices on their land are next to each other.

Table 7. Number of farms applying IFS models in different landscape units.

	HOMESTEAD			HOMESTEAD WITH RICE		CHAMKAR		
Province/commune	IFS M1	IFS M2	IFS M3	IFS M4	IFS M5	IFS M6	IFS M7	Total
Kampong Chhnang: 750 IFS farmers (383 represented by women; 367 by men)								
Peam	237	141	11	10	0	141	31	571
Chhean Laung	57	26	6	8	0	50	32	179
Pursat: 750 IFS farmers (477 represented by women; 273 by men)								
Phteah Rung	250	44	21	54	6	5	3	383
Ta Lou	134	135	30	35	29	3	1	367
Total	678	346	68	107	35	199	67	1,500
Percentage	**45.2**	**23.1**	**4.5**	**7.1**	**2.3**	**13.3**	**4.5**	**100**

Climate resilience of the farm builds on the analysis of existing farming technologies and how they cope with climate extremes. Six groups of SLM technologies have been identified (agroforestry, rotational systems, integrated soil fertility management, water management, small and large livestock production), out of which agroforestry, water management, and soil fertility management score highest in terms of resilience and farmer interest (production/market). Economic considerations, including access to markets and services, were assessed through the WOCAT SLM technology impact assessment and build an important pillar in the selection of the IFS models of the farmers. Further analysis is planned for a follow-up evaluation of the IFS models.

All of them improve cover condition, efficient use of irrigation water and rainwater, and soil fertility. Small and large livestock production showed the added value of manure management for other SLM technologies and its vital importance for an integrated farm system. All these improvements refer to the SLM principles, which are key for sustainable land management. This is achieved by improving water productivity (the water cycle), soil fertility (nutrient and organic matter cycle), plant management and the micro-climate (Liniger et al., 2011). In addition, all technology groups help to cope with extreme events related to storms and dry spells.

A key element of the approach is the understanding of the additional value of combining SLM technologies into context-specific IFS models, and the effective combination of these climate-resilient practices. Through these combinations, the SLM technologies are reinforcing and are being beneficial to each other to increase the overall performance of the farms. For example, an agroforestry practice in itself is already resilient where it is applied but also increases the resilience of neighbouring farming practices, e.g. through protection against storms, providing shade, and reducing runoff.

Co-production of IFS models

Co-production is a key ingredient for successful SLM as it brings together diverse societal actors and their perspectives, knowledge, and expertise (Pohl et al., 2021; Schwilch et al., 2012). It increases empowerment, ownership, and engagement, and is therefore considered fundamental to ensure sustainable development pathways in the agricultural sector (Reed et al., 2021). The presented approach highlights the principles of co-production and builds on the participatory WOCAT method and tools (Liniger et al., 2019), including different perspectives of various actors and gender-sensitive concerns related to impacts and resilience. Co-production through joint reflection, exchange, and mutual learning not only facilitates consolidating existing knowledge but also helps clarifying knowledge gaps and disagreements between different stakeholders, and thus the need for further investigations, and the development of new knowledge. Further, it was important to ensure that various actors, including disadvantaged groups, have a voice and their views are considered. As highlighted by Chambers et al. (2022), co-production processes can be challenging and require co-productive agility to navigate the various demands and expectations of various actors (including tensions and power dynamics). The joint assessment of farming landscapes and the tailored co-production of IFS models have been particularly valuable parts of the process.

A prerequisite of the co-production process was a strong multi-stakeholder engagement. Bringing together stakeholders from provincial to local levels through concerted efforts to jointly plan IFS implementation was not common in the two selected target provinces. Prior to our proposed IFS approach, planning of SLM interventions on a farm was done for single SLM technologies rather than for a combination of technologies. Furthermore, decisions for implementation were not based on well-documented experiences, and easily available knowledge bases, particularly considering the local biophysical conditions of the farms. To be able to develop suitable solutions that are attractive to farmers in their respective landscapes, context-specific knowledge is crucial. Previous experiences in the area show that, in some cases, farm plans were developed without considering the biophysical context (e.g. water availability for the selected crop), leading to challenges on the farm. The project was able to use existing knowledge and data such as Google Earth and satellite images, and the standardized WOCAT database and other sources related to SLM knowledge bases to support evidence-based decision-making processes. Results from the participatory assessment of the benefits/impacts of different SLM practices and their combinations were used for the development of farm plans.

Reflections on the approach

The aim of the SUCRA project was to develop a practical approach that can be implemented by extension workers in collaboration with farmers in the field. This approach uses open access data (e.g. Google Earth and WOCAT) and the building up of local context-specific knowledge about SLM. Furthermore, it aims to simplify complex interactions within farming systems by developing an easily applicable method. Our approach builds on a general understanding of the benefits and importance of IFS and recognizing landscape types, their potentials and limitations for implementing IFS.

This knowledge and understanding are generally not easily available in the provinces. Therefore, a strong capacity-building component is part of the approach including knowledge exchange between universities, NGOs, and the government (provincial and local authorities), and participatory workshops. Capacity building for farmers and CEWs at the village/farm level included trainings, field visits and the joint development of farm plans. This enabled stakeholders to improve their understanding and the use of SLM technologies, and their combinations into IFS. The IFS supported farmers in their intention to produce healthy and nutritious crops for their home consumption and for selling on the market and to reduce costs for external inputs.

Evidence on how the IFS has improved livelihoods and resilience to climate change will be generated through a participatory assessment framework in the years following implementation. The conditions before the implementation have been assessed, improvements and changes are planned to be monitored at the end of the project, and hopefully 5 years later. A methodology (participatory assessment framework) for a joint monitoring and evaluation (M&E) has been developed in a participatory way, including gender disaggregated data (Liniger et al., 2022). A baseline assessment has been made at the beginning of the project. The baseline as well as the end of the project M&E will be presented in a separate paper (forthcoming).

The approach is designed to be used and up-scaled by implementation agencies (e.g. governments, NGOs and development projects). However, the requirement on the necessary capacity and skills of planners and implementers remains a challenge for scaling up of IFS. Furthermore, initial farming inputs (e.g. seedlings) without external support remain a challenge for rural farming communities.

Conclusion

This study demonstrates a stepwise participatory approach on how smallholder farmers can develop landscape-specific IFS models to improve their farm resilience and livelihoods. Our approach aims to develop innovative and alternative climate-resilient farming models that foster sustainable farming landscapes in Cambodia. Our approach guides users through participatory steps and provides an assessment of the current farming systems and shows possible avenues for how the farming system can be diversified and made more resilient and productive.

The approach is suitable for upscaling to other areas/provinces in Cambodia, and countries in the Mekong region, as well as other countries/regions, in which smallholder farming is the focus. For these areas, the SLM knowledge base and the SLM technologies/groups to be combined into IFS models, will have to be built up. Proper monitoring and evaluation of the impacts of IFS will show the benefits and reveal constraints for large-scale implementation of IFS.

The principles of SLM and IFS models may also be integrated into prevailing agricultural commercialisation models in Cambodia. This would need to be further investigated. However, even on a larger farm, the principles of SLM combined in IFS need to be integrated and followed to ensure climate resilient-farming systems. The high diversity of different farming practices could also help to diversify semi- and commercialized farming systems with increased returns and reduced input costs. As such, the approach can be used as inspiration to develop alternative climate-resilient farming models for smallholder-led commercial agriculture to foster a sustainable agrarian transition in the Mekong region.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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