Modifying the farmer field school method to support on-farm adaptation of complex rice systems

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Abstract

Purpose. Complex rice systems (CRSs) are polycultures of plants and animals that enhance ecological processes contributing to sustainable and profitable farming systems. However, the contextual management complexity can hamper adoption, despite the large long-term benefits that CRSs offer. This paper aimed to provide a method that encourages active farmer involvement and integrates farmer's feedback to deliver timely adaptations to CRS management.

Design/methodology/approach. FFSs that are commonly used in guiding rural development processes involve a long process of preparation, weekly meetings and dissemination of new technologies with a greater knowledge flows from researchers or institutions to farmers than contrariwise. We have simplified FFS components and modified its curriculum focusing on extracting and integrating farmers' feedback into adaptation measures. Surveys were conducted and their results were validated through focus group discussions, which provided an adequate database to simplify the steps in the FFS approach. Findings. Only four meetings for agroecosystems analysis that emphasized an analytical and reflective learning cycle generated suitable adaptation measures selected from farmers' feedback. Repetition of the shortened FFS over several rice cropping cycles proved more effective than the frequent meetings within one cropping cycle. Practical implications. The modified FFS could be considered as a promising approach to training farmers, whilst simultaneously identifying and discovering adaptations of agricultural innovations and monitoring the evolution of complex polycultures like CRSs, under diverse conditions. Theoretical implications. The modified FFS provides participants additional time to reflect on the training topics, resulting in a significant improvement in their knowledge and the performance of the CRS. Originality/value. The modified FFS approach is focused on reflexive learning cycles and adaptation of innovations. Therefore, it is highly suitable for management of complex polycultures such as CRSs.

Keywords: agricultural innovations, farmer feedback, participatory learning, stakeholder participation, agricultural training, experiential and reflective learning

Introduction

Agricultural innovations can make significant contributions to address serious global crises such as hunger, malnutrition, health, poverty and environmental sustainability (Leitgeb et al., 2011; De Luca et al., 2018). However, innovations may be site or context specific, and not be transferable to other conditions. In these cases, innovations must be adapted to local conditions, instead of being presented as a fixed package of technological innovation (van der Venn, 2010; Droppelmann et al., 2017). Without making adaptations, the outcome of implementing a new innovation might not be satisfactory, even may experience difficulties during the adoption process.

Complex rice systems (CRSs) that combine elements of several agricultural approaches (e.g., mixed species, organic farming, '*jajarlegowo*' and the System of Rice Intensification, known as SRI) are a relevant example of innovation that potentially offers sustainable solutions to food security challenges (Cagauan, 2000; Khumairoh et al., 2012; Stoop et al., 2017). Recent studies demonstrated that rice yields under CRSs were higher and more stable than in conventional systems (Khumairoh et al., 2012; 2018). However, CRSs are also associated with a higher initial cost of species integration and increased management complexity (Khumairoh et al., 2012). For successful implementation of CRSs farmers must be equipped with sufficient skills and knowledge. This includes knowledge on managing mixed species in order to facilitate their synergetic interactions and their response to the biophysical conditions of rice fields, which are variable across locations and in time. Guiding the rural development process and knowledge sharing to inform adaptations to support CRS implementation requires understanding of the farmers and their farming context, as well as their 'decision spaces' (Blazy et al., 2009; Kuehne et al., 2017; Falconnier et al., 2017; Makate et al., 2018). This socio-technical contextual understanding of optionality and

challenges is a prerequisite for delivering timely and fitting adaptations to lubricate CRS management.

A participatory learning approach can effectively facilitate this experiential learning and adaptation process (Mackinson et al., 2011; von Münchhausen & Häring, 2012; Mancini, 2014), for example by using participatory learning of farmer field schools (FFSs). With its experimentation-based learning method that involves groups of participating farmers, FFSs offer a potential approach to disseminate adaptation measures tailored to local conditions, and could be used for the mainstreaming of CRSs. The positive outcomes of FFSs have been confirmed by their success stories in introducing knowledge of integrated pest management during the early 1990s, which reduced the use of chemicals in Indonesia (Van den Berg and Jiggins, 2007; Ketelaar and Abubakar, 2012; Pretty, 2015). However, as a means of agricultural technology diffusion (Kenya et al., 2017; Mcomvu and Mwajombe, 2016; Muilerman *et al.*, 2018), FFS implementation often emphasises dissemination rather than the adaptation of technologies (Muilerman et al., 2018), while integration of farmers' feedback is often overlooked. In addition, current FFSs also involve a long process of preparation and weekly meetings, making it a rather costly approach (Gallagher et al., 2006).

In response, we aimed to simplify and modify FFS components and its curriculum, enabling FFSs to extract local knowledge and feedback from farmers to identify and discover adaptation measures suited for local conditions in cheaper and more effective ways. To this end, we combined the FFS approach with elements of iterative learning methods (DEED; describe, explain, explore and design), which are commonly used to facilitate mutual co-learning to re-design farming systems (Groot and Rossing, 2011; Falconnier *et al.*, 2017; Descheemacker et al., 2016). Such re-design approaches can be employed to analytically: (i) characterize and describe the farming

context, farm resources, technologies and practices, (ii) explain the performance and constraints of production systems, (iii) explore innovative options to improve farm configuration based on farmers' observations and reflections, and (iv) redesign the farm based on the proposed ideas from earlier steps. FFSs are identified as the only generally applied approach for transferring knowledge to farmers in the rural areas of Indonesia, but their implementation is often impeded by limited resources (financially) and the static nature of the method. Therefore, we analysed the potential for simplification of FFS components and modifying its curriculum in order to provide a cost-effective and appropriate training approach for farmers.

Materials and Methods

Study sites

The study was conducted in four districts of East Java, Indonesia: Blitar, Malang, Pasuruan and Lamongan, where the shortest distance between the two sub-districts is 28 km, and the longest is 113 km (Figure 1). The features of the four districts including their farming background are displayed in Table 1.

[Figure 1 near here]

[Table 1 near here]

Participatory learning methodology

The study was carried out from June 2014 to June 2016 by employing an adjusted FFS method. This FFS method consisted of three main steps: preparation, implementation

and evaluation (FAO, 2016). In the original FFS set-up, each step consists of several activities, which are often repetitive and long-lasting. To improve its efficiency and to explore the potential of FFSs as a means for improving the adaptability of CRSs, we modified each FFS component (or step), which is illustrated in Figure 2.

[Figure 2 near here]

Step 1: Preparation

Surveys and Focus Group Discussions (FGDs) were performed as inception activities to understand the local context of rice farming systems and to prepare the implementation of CRSs. The surveys comprised interviews and farm visits to 119 farmer households to collect information of the biophysical characteristics, farming methods and the relation of farming to the environment and socio-economics (Table S1). The interviews consisted of semi-structured questions that were administered in Javanese and Indonesian languages by two people and lasted about 2.5 hours. We repeated the interviews to complete some missing information in the second visit or by phone calls. Questions were tested with 20 respondents, five respondents per district. The survey results were validated in a FGD with 7-10 key informant farmers and a representative of the local authorities per district.

The second FDG was designed to introduce CRSs and to select experimental farms while recruiting the FFS participants. A set of objectives to improve the current performance of rice farming systems was established, including increased rice yields and gross margins as well as product diversity and reduced agrochemical use.

The survey results were statistically analysed by ANOVA using normally distributed data sets. When transformation was necessary, log10 or square-root

transformed data were used to obtain normal distributions. Subsequently, Tukey post-hoc tests were employed to determine significant differences of the categorised variables between locations. A non-parametric statistical test of Kruskal-Wallis was also performed for data sets which were not normally distributed (labour inputs for weeding and fertilising). The results from this Kruskal-Wallis test were further followed by the post-hoc test of Mann-Whitney to determine the rank between groups tested.

Step 2: Implementation

The FFSs took place in farmers' fields, centred around on-farm experiments ranging in size from 1800 to 10,000 m² and comprising three repetitions of treatments. The treatments consisted of CRSs, conventional rice monocultures and organic rice monocultures. The original CRS design (Khumairoh et al., 2012) was tested at all study sites during the first cycle (rice cropping period) of the experiment, and adjusted to the local socio-biophysical conditions of each site in the second and third cycles. The working agenda is presented in Table S2. This FFS agenda was modified, including the agroecosystem analysis (AESA; a set of activities including observations and measurements of plants, animals and the environment), field days and an exchange programme. The AESA meetings were reduced from weekly to three to four times only during the most important stages of rice development, namely at tillering, booting, flowering or grain filling and harvesting. During the AESA meetings, farmers were guided to analyse and reflect on the results of their observations and measurements using the DEED method. Farmers were guided to describe and explain the constraints of the system tested and to explore solutions, providing feasible feedback. At the last meeting (i.e. at harvesting time), the feedback was discussed, reviewed and selected to re-design CRSs in the following cycles.

Step 3: Evaluation

A participatory evaluation was performed to assess the adaptation and performance of the CRSs after three cropping cycles. The assessment was made by asking farmers collectively to rank the performance of the CRSs in comparison with the conventional monoculture systems using six indicators. These indicators were established based on the objectives, including rice yields, self-sufficiency (feed and organic fertilisers), food diversity, gross margin and the environment. Moreover, one session was also allocated to test the farmers' knowledge. Ideally, the knowledge gained by farmers is evaluated by comparing the pre-test and post-test scores of FFS participants. However, when pre-tests are not possible, comparison to the knowledge of a control group of non-participants is also appropriate as demonstrated by Godtland (2004). The non-participants were selected from the same districts as the FFS participants, but were not familiar with our FFS project. The knowledge gained by the FFS participants was compared with the knowledge of non-participant farmers based on their mean scores of the test results. The questions tested farmer's understanding of recent agricultural innovations, existing management strategies of weeds, pests and nutrients, as well as polycultures. Differences were assessed by Cohen's *d* (Cohen, 1988):

$$d = \frac{M1 - M2}{SD_{pool}} \quad (1)$$

Where *M1* and *M2* are the mean test scores of FFS participants and non-participants, respectively, while the *SD pool* is the pooled standard deviation of the sample that was calculated as follows:

$$SD_{pool} = \frac{\sqrt{SD1^2 + SD2^2}}{2} \quad (2)$$

SD1 and SD2 represent the standard deviations for the test scores of FFS participants and non-participants, respectively. According to Cohen (1988) the effect size is small if $d=0.2$, medium if $d=0.5$ and large if $d=0.8$.

Results

Step 1: Preparation: rice system characterisation and challenges

Table 2 shows the strong contrasts between the districts in agronomic and socio-economic farm characteristics, which are relevant for CRS implementation. This frames the challenges associated with scaling out CRSs, which are shown in Table 3. For example, the high rice bunds in Lamongan could not be easily accessed by ducks to express their behaviour of intermittently walking to dry and wet spots for resting and playing. Narrow rice bunds in other districts could be broken during heavy rain when water flows suddenly and strongly, which would result in fish loss.

[Table 2 near here]

[Table 3 near here]

Annual rice production was highest for monocultures in Malang (16,6 Mg ha⁻¹ year⁻¹), while polyculture systems performed well in Blitar (16,2 Mg ha⁻¹ year⁻¹; Figure 3a). The lowest production was obtained in Lamongan ($F_{(7,111)} = 16.178$, $P < 0.001$; Figure 3a), resulting from a lower number of cycles per year (Table 2). However, the labour inputs per annum, especially for weeding in Lamongan were lowest ($X^2(7) = 94.732$, $P < 0.001$; Figure 3b), due to low weed incidence associated with the deep-water

systems (Table 2). Economically, the highest gross margin was obtained in the polyculture systems in Malang and the lowest in the conventional monoculture systems in Pasuruan ($F_{(7,111)}=4.212$, $P<0.001$; Figure 3c).

[Figure 3 near here]

Step 2: Implementation: CRS adaptations with modified FFSs

Modification of the FFS approach

The FFS components of Step 2 were modified to comply with our objectives as outlined in Table 4. During the implementation of FFSs, the number of meetings, timing, curricula and learning styles were modified. Morning meetings were only for AESA to minimise interruption of farmer working hours. A cross visit that was originally organised through the exchange visit programmes between two FFSs of different locations was changed into watching videos of other FFSs or farming practices in Lamongan and Blitar. Finally, the evaluation was focussed on farmer's knowledge gained and the performance of CRSs using indicators from Step 1.

[Table 4 near here]

Context-specific adaptations to CRS

Site-specific adaptation measures to overcome challenges during our study included (Table 5):

[Table 5 near here]

- Temperature: in Lamongan azolla was frequently imported as it did not grow well due to high temperatures (Nordiah, et al, 2012; Nhamo et al, 2014). Azolla grew well in Pasuruan and Blitar, but inoculants had to be imported for each cropping cycle. A nursery was built in Malang to supply inoculants for the next following rice cropping cycles. Growing border plants helped to substitute and complement azolla functions as animal feed and green manure, especially in Lamongan.
- Soil: the installation of plastic on the pond wall having calcareous and porous soil like in Malang retained water to support fish growth.
- Bund dimensions: the narrow rice bunds in Malang, Blitar and Pasuruan were widened, and the steep rice bunds in the deep rice water system in Lamongan were sloped to improve the ease of duck keeping in CRSs. Furthermore, heaping straw adjacent to the duck house and at some points in rice fields of the deep-water system in Lamongan facilitated flexibility for the ducks to rest. Straw was also eaten and decomposed by fish, increasing nutrient availability for rice.
- Resources (input): Growing high-biomass border plants increased feed and green manure self-sufficiency and provided shady areas for ducks and fish.
- Predators: Trap systems for predators of duck and fish proved useful for areas with predator problems, such as in Pasuruan. Providing open spaces, i.e. approximately 5% of rice fields without rice plants, reduced fish predation by snakes in Lamongan.
- Safety: Having fish and ducks in distant fields attracted theft. Ponds in Pasuruan and Malang were covered with tree branches to overcome this challenge. However, safety was not a concern in Lamongan where fish culture is prevalent.
- On-farm market: Fish culture combined with on-farm sales was practised in Lamongan. In Malang, Pasuruan and Blitar no market chain was developed. Hence,

farmers brought their produce to the closest traditional shop or market to sell their products, except for rice.

- Water level: A general adaptation was made by constructing deep trenches surrounding rice fields in the shallow-water rice systems in Malang, Blitar, and Pasuruan. In Malang, greater challenges with limited water availability and calcareous porous soil weakened fish and resulted in high mortality. Farmers suggested to distribute papaya leaves on the rice field as feed, believing that it has antiseptic, anti-parasitic and antimicrobial effects (Valladão, 2015; Jafari et al, 2018). Thus, three papaya trees were grown on rice bunds. A further adaptation was made by constructing a deeper pond separated by a rice bund with a gate for fish to access both rice field and pond. Instead of introducing fingerlings, tilapia fishes at three months of age are more tolerant and could hatch their eggs on the rice fields within a few days, resulting in fingerlings that rapidly adapted to the shallow rice ecosystems.

Step 3: Evaluation

The mean scores for knowledge about agronomic practices and innovations were higher for FFS participants than for non-participants ($t_{(25)}=12.634$, $P<0.001$; Figure 4). The Cohen's d index indicated a large effect of FFS training (larger than 0.8; Figure 4).

[Figure 4 near here]

Figure 5 demonstrates the results of participatory evaluation of farm performance throughout the three consecutive cropping cycles that were ranked on a scale by farmers. The perceived performance of CRSs was better than of conventional systems.

Having zero pesticides and herbicides, yet approximately 20-70% additional manure was produced by the ducks fed on azolla and sun hemp, the rice yields of CRSs were consistently higher than those from conventional systems, except for the first growing cycle in Blitar (Figure 5). The rice yields of CRSs in Malang were higher than in conventional during extreme weather. Without costs for agrochemicals, the increased quantity of edible and marketable products in CRSs resulted in a better gross margin than in the conventional system.

[Figure 5 near here]

Discussion

The initial purpose of designing CRSs was to exploit the roles of all integrated elements to suppress weeds and pests as well as to recycle nutrients effectively and ecologically, resulting in high rice yields and yield stability (Khumairoh et al., 2012; 2018).

However, the most optimal configuration of CRSs is highly dependent on the local socio-biophysical conditions, as well as the knowledge, skills and the attitude of farmers. This study highlighted the required adaptation process for implementation of CRS for contrasting specific conditions along with knowledge transmission to support the implementation of CRSs.

Adaptation of complex rice systems

Adapting CRSs within the local context and experiencing the benefits of these systems by farmers is essential for making them meaningful and relevant in solving current local

problems of rice farming. The adaptation process in the four districts in our study provided an example of how specific conditions challenged the implementation of CRSs. Variation of biophysical conditions such as temperature, soil, rice bund shape and water level have been identified as factors that influenced the variability of CRS performance. Some infrastructures were built or modified as measures to reduce the effects of biophysical heterogeneity, for example, expansion of rice bund and pond areas. Sun hemp, corn and other border plants were also added to substitute or complement azolla functions.

A step-by-step strategy allows for the prioritisation of specific objectives for individual farms during the conversion period. For example, overcoming the main problems of weeds and pests by duck integration was prioritised in Malang and Blitar, so that farmers could benefit immediately from the reduction of labour requirements, pesticides and herbicides. Contrastingly, in Lamongan, optimisation of rice bund areas with border plants was considered more straightforward and less risky and was therefore prioritised. In addition, the step-by-step strategy eased the financial constraint of initial capital requirements for implementation of CRSs (Khumairoh et al., 2012). This step-by-step strategy enabled distribution of investments over several cropping cycles to reduce the impacts of failure.

Modifications of the farmer field school approach

Farmers who want to shift from their current rice farming systems to CRSs require sufficient skills and knowledge to successfully implement CRSs on their rice farms. Training is considered as a major investment that positively correlates with farmer's attitude, adoption rates of agricultural innovations and farm performances (Mudombi 2013; Xayavong et al., 2016). The modification of FFS components in our study guided

farmers to produce feedback based on their indigenous knowledge that was restored during the AESA sessions. The modified FFS approach contributed significantly to improving farmers' knowledge as demonstrated in the mean examination scores (Figure 4). This suggests that a mere four meetings of AESA and seven meetings in total could lead to a substantial improvement in farmers' knowledge, demonstrating that a repetitive learning approach, spread over three cropping cycles is more important than the number of meetings per cycle per se.

The modifications to the number of the meetings, the flexibility of their timing, the number of FFS cycles followed and the curriculum enhanced the effectiveness of the FFS to deliver the objectives for CRSs adaptation. The use of the FFS approach to collect information and the capacity to improve CRS performance in this study shows the effectiveness of the adjusted FFS method as a means of innovation development.

Implications and suggestions for further research

Reducing the number of meetings from weekly to only 6-7 per rice cropping season certainly lowered FFS costs. The costs remaining can be allocated more effectively to repeat FFSs in consecutive rice cropping cycles to allow for the validation of the innovations tested under different weather conditions and other temporal variations. Lower costs, flexible timing and an optimised number of meetings make it possible for groups of farmers to organise FFSs by themselves in the following cropping cycles after the project finished, ensuring the sustainability of FFS as a means for farmers to update their knowledge and to gain or exchange information.

For practical implementation in Indonesia, the trade-off associated with the complexity of management of CRSs might be alleviated by implementing CRSs at a 'hamparan' scale, which is a cluster of small farms connected to each other, instead of

individual farms. This enables collective management, which may integrate other agricultural innovations to support CRS development. For instance, widening rice bunds may become a concern due to rat problems (Brown et al., 2003a; Hogan, et al., 2016) in endemic areas, which may be overcome with a trap barrier system (TBS) (Brown et al., 2006b; Kabir & Hosain, 2014). Implementation at ‘hamparan’ scale may also encourage construction of more permanent and shared infrastructures, creating shared security systems either from theft or predators, and may build a new market to sell the diverse products of CRSs. This may generate opportunities for a multi-stakeholder partnerships in the cluster that encourage landscape transformation and further development which are interesting subjects for follow-up studies.

The adaptation process in this study suggests that further studies are required to identify the numerous locally available resources that have similar functions and that could substitute or complement other elements to sustain the regulation of the ecological processes. Concerning the exchange programmes and field days in the FFS curriculum, they are essential for showcasing new innovations to a broader range of stakeholders. Augmenting those activities, for example by means of a farm contest, may attract other farmers to adopt the innovations. However, this needs to be developed further and should be tested for efficacy. The field day curriculum and the FFS exchange programme have not been investigated in detail. Thus, the question arises as to whether the modification of both the field day and the exchange programme will positively change farmers’ perspectives toward the new innovation, and therefore encourage further adoption.

Conclusions

We propose a modification and simplification of the FFS curriculum to enable integration of farmer's feedback into the process to make adaptation measures of CRSs effective. CRSs that outperformed conventional systems on FFS experimental farms demonstrated the adaptive capacity of CRSs and the potential of this modified FFS to support the development of agricultural innovations. Respecting the local context and active participation of farmers in our approach is particularly relevant for rural development process, thereby enhancing the multitude of potential adopters. By using this simpler modified FFS, this study contributes to the improvement of the FFS method as a means of knowledge exchange, equally between farmers and researchers, and to the enhancement of its cost-effectiveness, while showcasing the adaptation process of a new innovation. A key policy priority should be to plan implementation of FFSs in related to agricultural extension policy formulation. Broader implementation should be supported by supervision, capacity building and partnership with multiple stakeholders working in conjunction to enhance the sustainability and scalability of the innovative and adaptive CRSs.

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Table 1. The location and main farming activities of the study sites in four districts of East Java, Indonesia.

Variable	District			
	Lamongan	Pasuruan	Malang	Blitar
Coordinates	7°08'27,10''S- 112°23'46,79''E	7°41'49,82''S- 112°37'40,44''E	8°09'11,82''S- 112°34'33,32''E	7°59'34,14''S- 112°18'21,79''E
Altitude (m)	8	760	325	600
Soil type	Vertisol clay	Andisol sandy clay loam	Inceptisol silty clay (calcareous)	Entisol sandy
Mean temperature	26 °C	23 °C	24 °C	24 °C
Mean precipitation	1600 mm	3126 mm	2321 mm	3270 mm
Distance to larger town	50 km	59 km	118 km	150 km
Main farm products	Fish, rice, corn	Rice, vegetables	Rice, sugarcane	Rice, vegetables
Main livestock types	Chicken	Chicken	Chicken, duck	Chicken, duck, goat
Access to machinery	Renting, manual labor	Renting, use of animal traction	Renting, limited	Renting, limited

Table 2. Agronomic and socio-economic characteristics based on surveys on 119 farms in four districts of East Java, Indonesia.

Variable	District			
	Lamongan	Pasuruan	Malang	Blitar
Irrigation (% of farms)				
• Simple	-	43	-	-
• Semi-technical	100	27	22	28
• Modern	-	30	78	72
Bund size (cm)	>100	<40	<40	<40
Water level (cm)	40-60	<25	<25	<25
Bund height (cm)	75-100	<30	<30	<30
Transplanting method*	DS/TP	TP	TP	TP
Cycles per year (% of farms)				
• 1	7	-	-	-
• 2	93	39	22	40
• 2.5	-	-	78	60
• 3	-	61	-	-
Access to manure	Limited	Limited	Limited	Limited
Weed problems**	1	2	3	2
Pest problems	Snail, blast	Leafhopper	Rat, stemborer	Stemborer, rice bug
Polycultures (%)	93	67	37	40
Fallowing (%)	100	33	100	68
Pesticide (kg AI/ha/year)	0.7±0.08	1.5±0.18	2.4±0.30	2.4±0.24
Herbicide (kg AI/ha/year)	0.5±0.07	1.0±0.31	1.2±0.37	2.0±0.60
Artificial fert. (kg N/ha/year)	326±8.7	456±18.6	493±25.7	424±21.0
Organic fert. (kg N/ha/year)	2±0.7	24±5.6	37±16.0	4±14.1
Own:hired labor	0.76±0.07	0.82±0.15	0.73±0.09	0.85±0.04
Male:female labor	2.6±0.12	1.2±0.06	0.99±0.05	0.85±0.02
Markets other than rice	Fish and vegetables	-	-	-

*Planting: DS, direct seedling; TP, transplanting. **Weed problems: 1, minimum; 2, moderate; 3, acute.

Table 3. Challenges for the implementation of different CRS elements originating from biophysical and field conditions on rice farms in four districts of East Java, Indonesia.

Conditions	District			
	Lamongan	Pasuruan	Malang	Blitar
Temperature	Azolla	-	-	-
Soil	-	-	Fish	-
Rice bund dimensions	Ducks	Ducks, fish	Ducks, fish	Ducks, fish
Water level	Rice, azolla	-	-	-
Predators	Fish	Ducks	-	-
Resources (inputs)	Manure, azolla	Manure	Manure	Manure
Safety	Ducks	Ducks, fish	Ducks, fish	Ducks
Markets available	Ducks	Fish	All products	Ducks, fish

Table 4. Modifications of the FFS approach in relation to objectives of the method.

Objective	Original	Modified
Step 1: Preparation		
Analysis local context	Surveys, consultations, one full day PRA + transect walk	Surveys and FGD
Focus cropping period	One rice cropping cycle	Three cropping cycles
Step 2: Implementation		
Meetings per cycle	Weekly	Seven meetings
Timing	Half day always in the morning	3-4 mornings for AESA and the rest is flexible
Duration	4-5 hours	Approximately 3 hours
Participants	The farmer (head of family, mainly men)	Anyone representing a member of farmer household
Participant recruitment	Registered in the list of extension officers	Both from extension officers and selected randomly
AESA	OM, presentation and discussion	OM and DEED steps
Group dynamics	Games lead by facilitator	Any activities lead by anyone
Special topics	Focus on one commodity	Many commodities
Comparative learning	Cross visit	Either watching videos or cross visit
Experimental fields	One farm	Repetitions on multiple farms
Step 3: Evaluation		
Evaluation	Broad	Gained knowledge and CRS performances

Table 5. Adaptations to the CRS set-up dependent on the field configurations and constraints in four districts of East Java, Indonesia. Numbers indicate the rice cropping cycle (1st, 2nd or 3rd) in which the adaptation was implemented.

Conditions	Adaptation	District			
		Lamongan	Pasuruan	Malang	Blitar
Temperature	More additions azolla	1,2,3			
	Azolla nursery added			2,3	
	Planted border plants	2,3	2,3	2,3	2,3
Soil	Plastic wall fish pond			3	
Rice bund dimensions	Sloped	2,3			
	Ladder added	2,3			
	Straw heaps added	3			
	Widened bunds		2	2	2
Water level	Deep trenches		1,2,3	1,2,3	1,2,3
	Connected to pond		3	3	3
	Papaya leaves		2	2	2
	Use adult fish		3	3	3
Predators	5% pond area w/o rice plants	2,3			
	Traps		2,3		
Resources (inputs)	100% imports	1	1	1	1
	Border plants + manure 30%	2	2	2	2
	Border plants + manure 60%	3	3	3	
Safety	Tree branches covering pond		3	3	

Figure captions

Figure 1. Location of the farmer field schools to support the adaptation measures of complex rice systems.

Figure 2. Components of the three-step FFS method for CRS adaptation applied in four districts of East Java, Indonesia. CRS, complex rice system; FGD, focus group

discussion; FFS, farmer field school. Cycles 1 to 3 indicate consecutive cultivation periods of rice crops.

Figure 3. Performances of rice farms based on the surveys of 119 farm households in four districts of East Java. a) Labor inputs for weeding (LW), pest control (LP) and

fertilization (LF); b) Grain yields; c) Gross margin. M, monoculture; P/R, polyculture and/or rotation.

Figure 4. Knowledge level of FFS participants compared to non-FFS participants in the four districts of the study sites. FFS: farmer field school.

Lamongan

Pasuruan

Malang

Blitar

Figure 5. The results of the participatory assessment on CRS performance in comparison to the conventional rice production system using six indicators at four study sites in East Java, Indonesia. CRS, complex rice systems, CON, conventional.

Supplementary Material

Modifying the farmer field school method to support on-farm adaptation of complex rice systems

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Table S1. Variables collected for farm characterization in four districts of East Java, Indonesia.

Category	Variable	Unit
Physical conditions	Mean precipitation	mm year ⁻¹
	Mean temperature	°C
	Soil type	-
	Irrigation type	-
	Bund width	cm
	Water depth	cm
	Distance water surface to bund top	cm
Inputs	Pesticide use (active ingredients)	kg ha ⁻¹ year ⁻¹
	Herbicide use (active ingredients)	kg ha ⁻¹ year ⁻¹
	Artificial fertilizer nitrogen use	kg N ha ⁻¹ year ⁻¹
	Organic fertilizer nitrogen use	kg N ha ⁻¹ year ⁻¹
	Seedling transplanting method	-
	Number of rice cultivation cycles	year ⁻¹
	Rating of access to inputs	-
	Rating of weed problems	-
	Rating of pest problems	-
	Rating availability equipment and machinery	-
	Percentage of mono- and polycultures	%
	Percentage fallow	%
Farm performance	Rice grain yield	Mg N ha ⁻¹ year ⁻¹
	Labor use for weeding	h year ⁻¹
	Labor use for pest control	h year ⁻¹
	Labor use for fertilizer application	h year ⁻¹
	Gross margin	US\$ year ⁻¹
Socio-cultural setting	Ratio household / hired labor	-
	Ratio female / male labor	-
	Rating of organization level	-
	Rating of market access	-
	Other stakeholders involved	-

Table S2. Agenda of farmer field schools to support the adaptation of complex rice systems. AESA, agroecosystem analysis; DEED, describe, explain, explore, design; OM, observation and measurement. Cycles 1 to 3 indicate consecutive cultivation periods of rice crops.

Component	Rice cultivation cycle		
	Cycle 1	Cycle 2	Cycle 3
Meeting	1 introduction 3 AESA + special topic 1 harvesting, evaluation	1 introduction 4 AESA and special topic 1 harvesting, evaluation 1 field day and exchange	1 introduction 4 AESA and special topic 1 harvesting, evaluation 1 field day and exchange
Time	3 morning, 2 afternoons	4 mornings, 2 afternoons, 1 night	4 mornings, 2 afternoons, 1 night
Methods	Experiment, OM, DEED	Experiment, OM, DEED	Experiment, OM, DEED
Special topics	Duck-fish keeping, azolla growing	Border plants, feed management	Weed-pest-nutrient management, economics
Participants	Principal farmers, researchers	Principal farmers, neighboring farmers, researchers	Principal farmers, neighboring farmers, researchers, extension agents
Number of participants	20	40	80
Facilitator	Researcher	Researcher, principal farmer	Farmer, extension agent, researcher