Capacity building needs assessment: with a focus on System of Rice Intensification

Deliverable 1.1

This project has received funding from the Norwegian Agency for Development Cooperation (Norad) under Saksnr: *TAN-22/0005*

DOCUMENT SUMMARY		
Project Information		
Project Title:	Institutional capacity building on climate-smart and resource efficient rice production systems (with focus on System of Rice Intensification) in Tanzania	
Project Acronym:	SRI-Tanzania	
Grant agreement no,:	Saksnr: TAN-22/0005	
Project duration	Starting date: 01.12.2022	End date: 30.11.2025
Web-Site address:	https://resiliencetanzania.org/	
Project coordinators:	Norwegian Institute of Bioeconomy Research (NIBIO) Tanzania Agricultural Research Institution (TARI)	
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Report Information		
Deliverable no. and name	D1.1: Capacity building needs assessment (with a focus on System of Rice Intensification)	
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Work Package	WP1: Institutional Capacity building on climate smart and resource efficient agriculture production with emphasis on rice	
Work Package Leader	TARI	
Task no. and name	T1.1: Capacity building needs assessment	
Task Leader	TARI	
Dissemination Level	Public	
Deliverable Type	Report	
Delivery Date	August 2023	

Contents

Acronyms	**Full description**
ACT	Agriculture council of Tanzania
ASDP-II	Agriculture Sector Development Programme II
AWD	Alternate Wetting and Drying
DAFCO	District Agricultural and Fisheries Cooperative
GHGs	Green House Gases
IPM	Integrated Pest Management
LCC	Leaf Color Chart
MSSRF	M. S. Swaminathan Research Foundation- India
NIBIO	Norwegian Institute for Bioeconomy Research
NGOs	Non-Government Organizations
Norad	Norwegian agency for development cooperation
ToT	Training of Trainer
SRI	System of Rice Intensification
TARI	Tanzania Agricultural Research Institute
TAFSIP	Tanzania Agriculture and Food Security Investment Plan
VCs	Value Chains

Executive Summary

One of the main constraints contributing to low agricultural productivity in Tanznaia is lack of capacity at institutional and individual levels. To address this challenge, capacity building of human resources along the rice value chain is vital to contribute to agricultural development objectives and goals set by the Government of Tanzania. In this regard, there is need to increase competence and skills of the various stakeholders who are engaged in climate smart and resource efficient agricultural production with emphasis on rice production using the System of Rice Intensification (SRI) practices.

Capacity building and training needs assessment survey was carried out in the SRI-Tanzania project areas in selected representative sites in two regions namely Mbeya and Iringa during April 2023. Purposive sampling method was used to identify study districts and representative study irrigation schemes where rice is grown. The structured questionnaire survey addressed topics related needs assessment in crop management, water and soil management, rice value chain and marketing. One of the outputs from the survey was a deliverable report (D1.1) that has identified the knowledge gaps among the target groups (farmers, extension officers and researchers), the training and skills needed in implementing the SRI practices.

The findings revealed that the concept of SRI was not new to most of the respondents but they lack knowledge and skills in implementing the basic SRI practices. This is in relation to transplanting young and single seedlings and proper land leveling. Planting of young seedlings especially the uprooting of seedlings from the nursery site was the most tedious and time consuming. Farmers were not aware of using mat nursery that helps to ensure less seedling damage, easy uprooting and provide enough time for transplanting. Many farmers and extension officers had insufficient knowledge about planting in rows, applying alternate wetting and drying irrigation using Panpipe, wider plant spacing. Site specific nutrient management approach using leaf color chart and integrated pest management practices such as yellow insect traps, were new to the farmers.

Based on the findings, a first round of training of trainees (that include extension workers and researchers) was held in the rice fields of the project sites preceeded by teaching the basic principles of SRI in the classroom. The training programme was organized by TARI and it was given by two rice experts from India and NIBIO staff. The trainees will train the lead farmers who will inturn train fellow farmers following the training plan.

Several research findings have shown that SRI adoption contributes to high yield per unit area as compared to paddy cultivation. To increase adoption of SRI at farm level, institutional capacity building through customized trainings and field demonstration using simple and locally available materials are required, which is the main objective of work package 2 of this project. However, large scale SRI adoption will require institutional and policy support for examples investments to improve irrigation infrastructures, access to machinery for field operations including land leveling.

1 Introduction

Rice is one of the staple foods for many African countries including Tanzania which constitutes a major part of the diet. In Tanzania, rice is one of the priority food crops that support agricultural development and economic growth (Wilson and Lewis, 2015; TAFSIP, 2011; NRDS, 2009). It is mainly grown under upland rain-fed conditions (about 80-90 %) and about 10-20% is grown in irrigation schemes. The rice yields under rainfed conditions are low (on average 1-2 ton/ha) against the potential of 6 tons/ha in improved conditions. The main biophysical constraints contributing to low rice productivity include *poor quality seeds, in adequate and uncertain water supply, improper fertilization, pest, diseases and weeds and climate variability in the form of extreme weather events* (Aune et al., 2014). Even under irrigated rice, lack of proper water usage and management is often poor leading to poor crop harvests.

Climate change adversely affect rice production systems and the rice production environment due to increasing water shortage needed for irrigation. At the same time current rice production systems are constrained by high costs of inputs such as seeds ranging between 15 to 40 kg/ acres, high costs of nursery preparation and management, high and unnecessary input use especially fertilizer even when information on fertilizer recommendations are available. Land levelling is another issue contributing to poor water management. With water increasingly becoming a scarce resource, it is important to bring in innovative methods for efficient utilization of water. In order to increase efficiency in rice production systems, it is important to increase productivity per unit area, by adopting innovative practices such as system of rice intensification (SRI).

Table 1.1: Principles and/or practises of SRI and their main functions along with references.

SRI principles/practices	*Functions*	*References (e.g.)*
• Transplanting young seedlings of **12-15 days old**	• Increases tiller numbers, facilitates root development, and enables early maturity thereby escaping dry spells	• Katambara (2013); Kahimba, et al., (2014)
• Transplanting single seedling with **2-4 leaves** stage per hill	• Reduces competition for water, nutrients & light, enables deeper root growth; & more tillers	• Toriyama and Ando (2011)
• Wider spacing (**25 cm × 25 cm**) and planted in lines/rows	• Facilitates aeration, encourages greater root and canopy growth	• Reuben, P. et al., (2016)
• **Inter-cultivation between rows** using hand/rotary weeding	• control weeds, pests/diseases, and promotes soil aeration.	• Thiyagarajan and Gujja (2013)
• Controlled intermittent irrigation/ **alternating wetting with drying**	• Better soil aeration, saves water through intermittent water applications	• Materu, S.T. et al (2018); Alavaisha et al., (2022)
• **Organic fertilizer** and mineral fertilizers (as needed)	• Enhances soil health (e.g., fertility, carbon storage), reduced GHG emission	• Mboyerwa, P.A. (2018)

SRI innovation is based on six principles namely, growing young seedlings aged between 8- 15 days, single plant per hill, wider spacing of 25 cm x 25 cm, alternate wetting and drying (AWD), inter cultivation mechanical weeding and more use of organic fertilizers. The basis for SRI principles is further explained in Table 1.1. SRI is based on the principles of '*achieve more with less inputs'* of seeds, water, fertilizers, and/or pesticides while improving rice productivity. The increase in rice productivity through SRI is mainly due to improvement in the management of plants, soil, water and nutrients (e.g., Thiyagarajan and Gujja, 2013).

Tanzania Agricultural Research Institute (TARI) and the Norwegian Institute of Bioeconomy Research (NIBIO) are embarking on project (i.e. SRI-Tanzania project: https://resiliencetanzania.org/ that seeks to increase the capacity of farmers and other value chain actors thereby adopt innovative technologies for rice production with a focus on SRI. Capacity building of human resources both at institutional and individual level along the rice value chain is vital to contribute to agricultural development objectives and goals set by the Government of Tanzania. Capacity building needs assessment exercise is meant to assess the current state of knowledge and gaps that will form the basis for designing training plans tailored towards available resource and needs. In connection to this, there is need to increase competence and skills of the various stakeholders who are engaged in rice production in particular on SRI practices.

The SRI-Tanzania project of Work Package (WP) 1 addresses the issues mentioned above. The objective of WP1 is *to build on the existing knowledge, experiences, skills, and gaps of targeted groups/actors of rice value chain.* The main targeted groups include smallholder farmers, extension workers, scientists, and other relevant value chain (VCs) actors in the study districts where rice is grown using rainfed and/or irrigation systems. WP1 is led by TARI, co-lead by NIBIO, and supported by multi-stakeholders who are engaged throughout the project life. Under WP1, there are three main tasks and a number of subtasks that are executed by the project partners. One of the tasks under WP1 is Task 1.1: Capacity building needs assessment. The objective of Task 1.1 was to identify the knowledge gaps among the target groups and ascertain the training and skills need in climate smart and resource efficient agricultural production with emphasis on rice. It is assumed that the needs assessment survey findings will serve as the starting point for planning capacity development activities and for enhancing institutional collaboration among all stakeholders.

2 Description of the study sites

SRI-Tanzania project will test SRI practices in five selected districts of rice growing areas of Tanzania to address the main constraints of rice productivity (Figure 2.1). The project study sites are mainly irrigated rice where intensive water use is common (Table 2.1). Most of these farmers use improved seeds that are purchased from different sources such as research institution, seed retailers and Quality Declared Seed (QDS) farmers.

Table 2.1: Case study regions and districts in SRI-Tanzania project

Region	Districts	Irrigation schemes	Descriptions
Mara	Bunda	*Mariwanda*	Improved irrigation scheme with poor water management and leveling
Pwani	Kibaha	*Ruvu*	1000 ha improved irrigation scheme with poor leveling and water management challenges
Morogoro	Kilombero	*Mkula*	Traditional irrigation scheme with poor drainage and poor leveling
		Msolwa	Traditional irrigation scheme with poor drainage and levelling
		Sagamanga	Traditional irrigation scheme with water management challenges

			and poor levelling
Iringa	Iringa	*Pawaga*	Semi improved irrigation schemes
		Idodi	Traditional irrigation scheme
Mbeya	Mbarali	*Madibira*	Improved irrigation schemes with improved mechanization in field operation and water supply, and certain levels farmers' organization
		Uturo	Tradional irrigation scheme

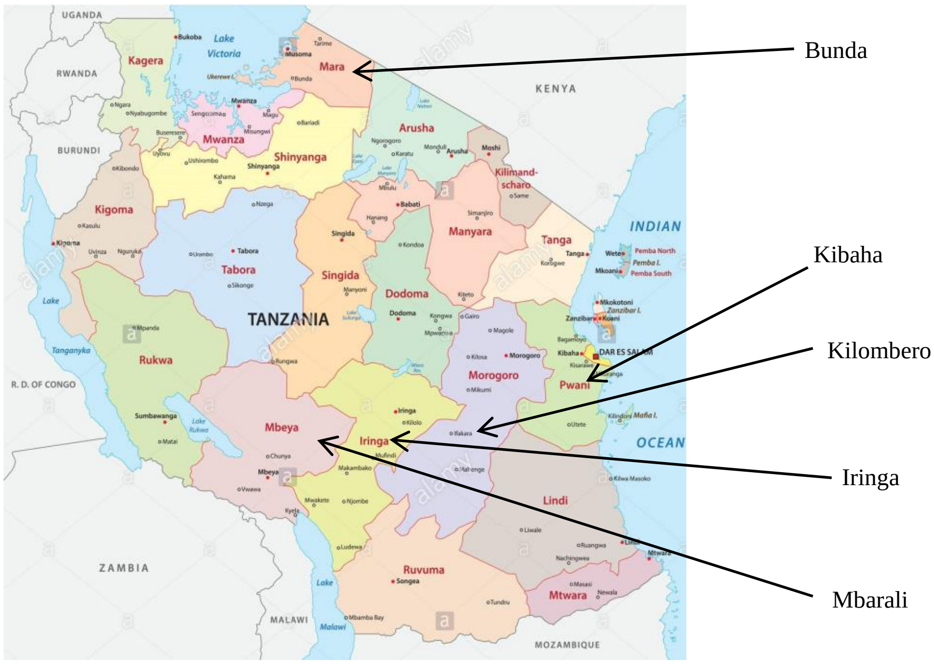


Figure 2.1: Location map of the project districts in Tanzania.

3 Methodology

3.1 Research design

The study used cross-section design on which data were collected at one point in time. According to Babbie (1990) the cross-section design is the most appropriate approach for household surveys as it facilitates identification of the population of interest, and it is cost effective and less time consuming.

i) Scope of work and questionnaire design

Current human and institutional resources, capacity needs on climate smart rice production, with emphasis on SRI, was reviewed from published and grey literatures. Previous review studies related to SRI in Tanzania (e.g., Nagothu et al., 2019) was used to refine the scope of the current assessment needs of the capacity building. Critical knowledge gaps (including gender bias) and opportunities for capacity building was identified by conducting interviews in selected study sites. Information collated from the review and interviews were discussed with the target groups.

A semi-structured questionnaire was prepared that quests information related to: i) background information of respondent, ii) crop management (including pest, weed and diseases), iii) innovation platform for SRI uptake, iv) soil and water management, v) knowledge dissemination (by extension workers) and stakeholder engagement, and finally vi) rice value chain and marketing. Information collated from the literature review and interviews were discussed with the target groups.

ii) Sampling procedure and data collection

Multi-stage purposive sampling procedure was used to select two regions, namely Mbeya and Iringa from the five project regions. The SRI training needs survey was conducted in *Mbarali* and *Iringa* districts, assuming that they represent the other project districts in the level of knowledge on SRI practices, similar pedoclimatic and socioeconomic conditions. In each district, two irrigation schemes were purposively selected, making a total of 4 study irrigation schemes. A sample of 30 rice farmers were drawn from each irrigation schemes (Table 3.1). This makes a total sample size of 120, i.e., 60 per each district. The list of respondents was obtained from the irrigation committee leaders.

Table 3.1: Study Schemes and sample size 2023

Region	District	Irrigation Scheme	Sample size (n)		
			Total	Male	Female
Mbeya	Mbarali	Madibira	30	19	11
		Uturo	30	18	12
Iringa	Iringa	Mlenge	30	18	12
		Idodi	31	20	11
Total			**121**	**75**	**46**

Source: Field survey results 2023

3.2 Data sources and methods of data collection

Both primary and secondary data were collected to ascertain the training needs of the different stakeholders with a focus on SRI practises. Primary data were collected from selected rice farmers through individual interviews using questionnaires. In the process, both quantitative and qualitative data were collected. The interview team also used direct observation as a strategy to combine more information on key parameters. Both open and close-ended questions were used to collect the data. The questionnaire was administered using Kobo data collection tool (KoboCollect App). Prior to the survey, the tool was pretested, and then the survey was conducted in February, 2023.

Secondary information that are relevant to the study, was collected from published and unpublished sources of different institutions at the district, region, and national levels**.** For example, TARI centres Mbarali and Iringa district agricultural, fisheries cooperative (DAFCO) offices in the respective districts. The information gathered was used to complement missing information that could not be captured during the interview.

3.3 Data analysis and processing

Data from individual farmer interviews were subjected to descriptive statistics in terms of percentages or frequencies using IBM SPSS statistics (version 23, USA). A Chi-square test of independence ($p < 0.05$) was performed to determine if there was significant difference between and/or among assessed SRI parameters disintegrated by respondents' locations (*schemes* and *regions*) and *sexes*. The chi-square test was performed independently for each individual option in the multiple response questions. For acreage under rice production and its productivity data, as well as application rates for mineral fertilizer; the independent sample t-test *($p < 0.05$)* was computed to evaluate any significant difference between regions and sexes, while a one-way ANOVA analysis was performed using Tukey's test *($p < 0.05$)* for multiple comparison among schemes. Qualitative data gathered through "open end questions" were content analyzed before coded for quantitative analysis.

4 Survey findings and Discussion

4.1 Demographic profile of respondents

Some of demographic profile of interviewed farmers in the surveyed irrigation schemes and administrative regions is presented in Table 4.1. On average, 62 percent were male and 38 were female respondents having similar pattern for both Iringa and Mbeya regions. Young adults (20-40 years) constituted about 43%, while old people were less than 2% of those interviewed. This indicates that the youth have a pivotal role to play in the rice production system.

Table 4.1: Profile of respondents (as percentages) in the surveyed schemes and administrative regions

	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
Sex								
Male	60.0	64.5	63.3	60.0	62.0	62.3	61.7	62.0
Female	40.0	35.5	36.7	40.0	38.0	37.7	38.3	38.0
Age group (years)								
20-40	46.7	38.7	33.3	53.3	43.0	42.6	43.3	43.0
41-50	30.0	32.3	30.0	30.0	30.6	31.1	30.0	30.6
51-60	20.0	19.4	13.3	16.7	17.4	19.7	15.0	17.4
61-70	3.3	9.6	16.7	0.0	7.4	6.6	8.3	7.4
70+	0.0	0.0	6.7	0.0	1.7	0.0	3.4	1.6
Marital status*								
Single	6.7	9.7	3.3	0.0	5.0	8.2	1.7	5.0
Married	86.6	87.1	83.3	90.0	86.8	86.9	86.7	86.8
Separated	6.7	0.0	0.0	10.0	4.1	3.3	5.0	4.1
Widow/er	0.0	3.2	13.4	0.0	4.1	1.6	6.6	4.1
Educational level*								
Primary	86.7	71.0	56.7	86.7	75.2	78.7	71.7	75.2
Secondary	13.3	25.8	43.3	13.3	24.0	19.7	28.3	24.0
College	0.0	3.2	0.0	0.0	0.8	1.6	0.0	0.8

[a]Combine family-owned land and community own land; [b]Combine grain legumes /beans, peanuts, roots and tubers, and sorghum; [$]More than one answer possible; *Significance difference among schemes at *$p < 0.05$*; [β]Significance difference between regions at *$p < 0.05$*

About 76% of the respondents owned land and/or had leased land ownership. The proportion of farmers who either community/own land are high in the Mbeya region. This has an implication on the land tenure security that encourages long term investments for increasing rice productivity (Table 4.2).

Table 4.2: Land ownership types and farming system (as percentages) in the surveyed schemes and regions

	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
Land ownership[$]								
Own land*	80.0	64.5	66.7	93.3	76.0	72.1	80.0	76.0

Leased land	60.0	61.3	73.3	66.7	65.3	60.7	70.0	65.3
Others*[a]	13.3	35.5	26.7	3.3	19.8	24.6	15.3	20.0
Other crops grown[$]								
Maize*[β]	68.8	92.6	100	100	92.6	83.7	100.0	92.6
Sunflower*	37.5	29.6	48.1	4.0	29.5	32.6	26.9	29.5
Vegetables*[β]	43.8	11.1	7.4	0.0	12.6	23.3	3.8	12.6
Others*[b]	50.0	29.6	48.1	4.0	31.6	37.2	26.9	31.6

[a]Combine family-owned land and community own land; [b]Combine grain legumes /beans, peanuts, roots and tubers, and sorghum; [$]More than one answer possible; *Significance difference among schemes at $p < 0.05$; [β]Significance difference between regions at $p < 0.05$

4.2 Needs assessment in Crop management

In this section, rice cultivation area, rice crop establishment practices, rice production systems, factors affecting rice yield, weed control measures, and rice straw management practices implemented in the case study sites, are presented from Tables 4.3 to Table 4.8.

Accordingly, the average rice cultivated area per farmer ranged between 2.8 to10 acres (about 1,1 to 4,0 ha). The highest acreage was reported in Madibira followed by Mlenge irrigation schemes while Uturo reported the smallest area (Table 4.3) Uturo shceme is mainly traditional scheme with improved water canals also the it is stuated in a highly populated area where there is land scarcity. However, the productivity of rice (6.9 t/ha) in Uturo was the highest than the others probably due to using improved crop management practices. But also small plots are easy to manage in terms of farm management practices.

Table 4.3: Acreage under rice production and its productivity in the surveyed area

	Mean values ± Standard error mean				
	Area under rice cultivation (acre)	Harvested paddy (bags, 90 kg)	Harvested paddy (t/ha)	Productivity (bags/acre)	Productivity (t/ha)
Irrigation schemes					
Mlenge (n=30)	5.4 ± 0.8^{a}	94.0 ± 11.9^{a}	8.5 ± 1.1^{a}	19.3 ± 1.4^{ab}	4.3 ± 0.3^{ab}
Idodi (n=31)	4.3 ± 0.5^{a}	69.1 ± 10.0^{a}	6.2 ± 0.9^{a}	16.0 ± 1.3^{a}	3.6 ± 0.3^{a}
Madibira (n=30)	10 ± 2.6^{b}	287 ± 82.0^{b}	26 ± 7.4^{b}	25.7 ± 2.5^{bc}	5.8 ± 0.6^{bc}
Uturo (n=30)	2.8 ± 0.3^{a}	81.5 ± 10.2^{a}	7.3 ± 0.9^{a}	31.0 ± 1.8^{c}	6.9 ± 0.4^{c}
Regions					
Iringa (n=61)	4.9 ± 0.5	81.3 ± 7.8	07.3 ± 0.7	17.6 ± 1.0	4.0 ± 0.2
Mbeya (n=60)	6.6 ± 1.4	184 ± 43	16.6 ± 3.9	28.3 ±1.6	6.4 ± 0.4

Values in each column bearing different superscripted letters are statistically different ($p < 0.05$) among schemes
*Significance difference between regions (at p < 0.05, independent T-test).

Majority of the farmers (in the case study irrigation schemes) practice line planting with old seedlings and a few percentages of them planting in dibbling (Table 4.4). Because of the perceived high cost of labour in and technicalities of principles of SRI many aspects of SRI such as use of young seedlings and line planting. With exception of Mlenge a small proportion of farmers in other surveyed irrigation scheme report to use line planting while at Mlenge about 13 percent of the respondent practice dribbling as a method used for crop establishment. The use old seedlings with average age of 21 days are common practice across all irrigation schemes in the survey area.

Table 4.4: Overview rice crop establishment practices as percentages of respondents in the surveyed areasregions

Planting	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
*Planting dibbling**								
Not at all	80.0	93.5	93.3	100	91.7	86.8	96.7	91.7
Rarely	6.7	6.5	6.7	0.0	5.0	6.6	3.3	5.0
Mostly	13.3	0.0	0.0	0.0	3.3	6.6	0.0	3.3
Line planting								
Not at all	70.0	61.2	73.3	66.7	67.8	65.6	70.0	67.8
Rarely	30.0	32.3	20.0	30.0	28.1	31.1	25.0	28.1
Mostly	0.0	6.5	6.7	3.3	4.1	3.3	5.0	4.1
Planting young seedlings								
Not at all	70.0	67.7	86.7	63.3	71.9	68.9	75.0	71.9
Rarely	23.3	22.6	10.0	36.7	23.1	23.0	23.3	23.1
Mostly	6.7	9.7	3.3	0.0	5.0	8.1	1.7	5.0
Planting old seedlings								
Not at all	3.3	3.2	0.0	3.3	2.5	3.3	1.7	2.5
Rarely	10.0	6.5	0.0	3.3	5.0	8.2	1.7	5.0
Mostly	86.7	90.3	100	93.4	92.5	88.5	96.6	92.5

*Significance difference among schemes at $p < 0.05$; $^{\beta}$Significance difference between regions at $p < 0.05$

In the project areas, more than 90% of the rice production system is characterized by irrigated lowland systems with transplanting rice (Figure 4.1).

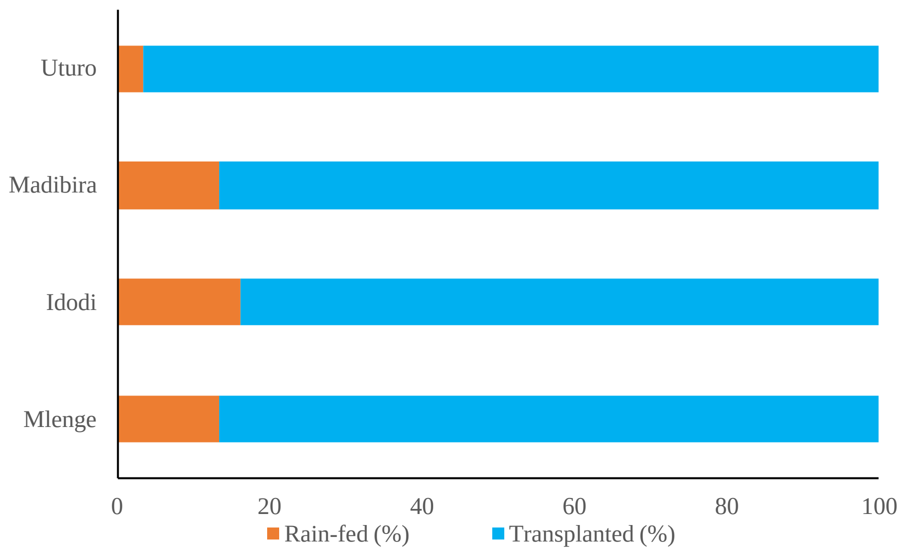


Figure 4.1: Rice production system in the surveyed irrigation schemes.

There are a number of production challenges faced by farmers in the study area. Extreme weather events particularly drought was rated high followed by lack of capital to invest on rice production and unavailability of resources. In this regard, poor infrastructure was responsible for water shortage and the trend was similar across the two regions of Mbeya and Iringa (Table 4.5). Within the study area Idodi seem to be affected by extreme weather particularly water shortage. This is the fact that irrigation water is rainfall dependent upstream couple underdeveloped rice fields. Lack of capital also features across all locations as the biggest challenge especially with purchase of inputs such as fertilizer and agrochemicals. Thus, it is important to establish cooperatives and purchase inputs in bulk also encourage the use of other types of manure for soil fertility improvement

Table 4.5: Factors affecting rice yield (as percentage of respondents) in the surveyed area.

Factors affecting rice yields[$]	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
• Extreme weather events*	33.3	80.6	56.7	56.7	57.0	57.4	56.7	57.0
• Lack of SRI skills*	30.0	9.7	23.3	3.3	16.5	19.7	13.3	16.5
• Lack of capital	56.7	51.6	50.0	53.3	52.9	54.1	51.7	52.9
• Unava. of resources*$^{\beta}$	46.7	38.7	73.3	66.7	56.2	42.6	70.0	56.2
• Pests	13.3	16.1	20.0	10.0	14.9	14.8	15.0	14.9
• Weeds*$^{\beta}$	16.7	38.7	20.0	0.0	19.0	27.9	10.0	19.0
• Diseases	6.7	16.1	10.0	0.0	8.3	11.5	5.0	8.3
• Poor soil fertility	6.7	22.6	20.0	10.0	14.9	14.8	15.0	14.9
• Lack of irrigation infr.*$^{\beta}$	26.7	25.8	10.0	3.3	16.5	26.2	6.7	16.5
• Lack of water for irrigation*$^{\beta}$	40.0	25.8	10.0	3.3	19.8	32.8	6.7	19.8
• Flooding	6.7	9.7	3.3	6.7	6.6	8.2	5.0	6.6
• Others[a]	30.0	16.1	20.0	3.3	17.4	23.0	11.7	17.4

[a]Combine invasion by elephants and birds, late cultivation, taking farming for granted, sand accumulation in water canals; [$]More than one answer possible; *Significance difference among schemes at $p < 0.05$; $^{\beta}$Significance difference between regions at $p < 0.05$

The introduction of SRI practices could be an option to tackle some of the above-mentioned challenges faced by farmers like water and seed shortage. SRI provides water rationing and less frequency of irrigation while ensuring high yield at the same time. Moreover, it reduces seed requirement by over 60 percent. Irrespective of location, all respondents reported similar production challenges and ranked them in more or less the same order. With regard to weed control practices hand weeding and the use of herbicide were common especially in irrigated areas. However, it was noted that farmers lack knowledge on proper herbicide application in terms of timing, dosage and right type of herbicide. Additionally, there is problem of water pollution due to poor disposal of used chemical containers and pose s great risk to human and environment.

Table 4.6: Weeding practices implemented as percentages of respondents in the surveyed area

Weeding	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
Mechanical weeding								
Not at all	83.4	100	96.7	90.0	92.6	91.8	93.3	92.6
Rarely	13.3	0.0	3.3	10.0	6.6	6.6	6.7	6.6
Mostly	3.3	0.0	0.0	0.0	0.8	1.6	0.0	0.8
*Chemical weeding**$^{\beta}$								
Not at all	6.7	3.2	0.0	0.0	2.5	4.9	0.0	2.5
Rarely	23.3	3.2	3.3	0.0	7.4	13.1	1.7	7.4
Mostly	70.0	93.5	96.7	100	90.1	82.0	98.3	90.1
Hand weeding								
Not at all	0.0	3.2	0.0	0.0	0.8	1.6	0.0	0.8
Rarely	3.3	0.0	0.0	0.0	0.8	1.6	0.0	0.8
Mostly	96.7	96.8	100	100	98.4	96.8	100.0	98.4

*Significance difference among schemes at $p < 0.05$; $^{\beta}$Significance difference between regions at $p < 0.05$

Weed control measures are mostly implemented using hand weeding and most farmers hardly use mechanical weed control measures (Table 4.6). The high cost of herbicides and lack of cash/capital mainly deters farmers from applying chemicals to control weeds (Table 4.7). because the majority of farmers do not plant in rows weeding using machinery like push weeders is not possible even by hand weeding it is rather less efficient as many weeds remain in the field prompting several rounds of weeding which makes it expensive. In areas with high weed regrowth there is growing trends towards use of herbicides to control weeds thus the introduction of push weeders and cono weeders could encourage planting in rows

Table 4.7: Main challenges of weeding control as percentages of respondents in the surveyed area

Challenges$^{\$}$	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
• High cost of herbicides	22.2	5.3	30.0	0.0	12.5	10.7	15.0	12.5
• Lack of cash/capital*	33.3	0.0	0.0	0.0	6.2	10.7	0.0	6.2
• High weed infestation	22.2	5.3	10.0	0.0	8.3	14.7	5.0	10.4
• Fake agrochemicals	0.0	15.8	10.0	0.0	8.3	10.7	5.0	8.3
• Herbicide resistance by weeds	0.0	21.1	10.0	0.0	10.4	14.3	10.0	12.5
• Long weeding time	11,1	0.0	10.0	0.0	4.2	3.6	5.0	4.2
• Lack of weeding implements	0.0	0.0	0.0	10.0	2.1	0.0	5.0	2.1

Majority of the farmers in the surveyed area do not burn rice straw in the fields, but rather removed the straws and use it for different purposes like for livestock feeding, construction or fuel (Table 4.8). This implies that rice straws are not incorporated into the soils which would have redressed the nutrients removal by the harvested crops and other associated soil fertility declining factors. A few farmers reported to burn the straws in the field to avoid grazing animals by cattle keepers because the cause soil compaction. However burning is not advisable as it results the killing of beneficial microorganisms responsible for soil structure improvement

Table 4.8: Rice straw management practices implemented as percentages of respondents in the surveyed areas

Rice straw	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
Burned								
Not at all	86.7	67.7	73.4	76.7	76.0	77.0	75.0	76.0
Rarely	0.0	6.5	13.3	10.0	7.5	3.3	11.7	7.4
Mostly	13.3	25.8	13.3	13.3	16.5	19.7	13.3	16.6
Removed out of the field$^{*\beta}$								
Not at all	30.0	32.2	63.4	70.0	48.8	31.1	66.7	48.8
Rarely	13.3	19.4	13.3	26.7	18.2	16.4	20.0	18.2
Mostly	56.7	48.4	23.3	3.3	33.0	52.5	13.3	33.0
Ploughed more than 30 day before flooding the field								
Not at all	90.0	83.9	83.3	93.3	87.6	86.9	88.3	87.6
Rarely	10.0	9.7	3.3	6.7	7.4	9.8	5.0	7.4
Mostly	0.0	6.5	13.3	0.0	5.0	3.3	6.7	5.0
Ploughed less than 30 days before flooding the field$^{*\beta}$								
Not at all	93.3	77.4	60.0	60.0	72.7	85.2	60.0	72.7
Rarely	6.7	19.4	20.0	20.0	16.6	13.1	20.0	16.5
Mostly	0.0	3.2	20.0	20.0	10.7	1.6	20.0	10.8

*Significance difference among schemes at $p < 0.05$; $^{\beta}$Significance difference between regions at $p < 0.05$

4.3 Needs assessment in Water and Soil management

Under this section, findings from the interview related to water and soil management practices implemented and their key challenges are presented in Tables 4.9 to 4.14. With regard to irrigation methods, majority of the farmers cultivate rice under flooded or paddy conditions. The application of AWD irrigation method in the rice fields is not common among the interviewed farmers (Table 4.9). Introducing AWD (one of the components of SRI practice) could help farmers in the area to save water while maintaining the productivity and use the saved water for growing other crops.

Table 4.9: Overview irrigation practices as percentages of respondents in the surveyed regions

Irrigation method	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
*Flooding (paddy)**								
Not at all	3.3	16.1	20.0	6.7	11.6	9.8	13.3	11.6
Rarely	6.7	19.4	3.3	23.3	13.2	13.1	13.3	13.2
Mostly	90.0	64.5	76.7	70.0	75.2	77.0	73.4	75.2
Alternate wetting and drying (AWD)								
Not at all	53.3	32.2	43.4	46.7	43.8	42.6	45.0	43.8
Rarely	40.0	45.2	33.3	43.3	40.5	42.6	38.3	40.5
Mostly	6.7	22.6	23.3	10.0	15.7	14.8	16.7	15.7

However, the main challenges of introducing AWD include poor field leveling and lack of water outlets from paddy fields, should be first tackled (Table 4.10). Farmers can use simple wooden frames (locally produced) to level their fields and construct field channels to discharge excess water from the paddy fields.

Table 4.10: Main challenges of practicing AWD as percentages of respondents in the surveyed area

Challenges$	Mlenge (n = 9)	Idodi (n = 19)	Madibira (n = 10)	Uturo (n = 10)	Mean	Iringa (n = 28)	Mbeya (n = 20)	Mean
Challenges of AWD								
• Poor field levelling	33.3	21.1	30.0	30.0	27.1	25.0	30.0	27.1
• Lack of water outlets from paddy fields $^{\beta}$	44.4	31.6	0.0	20.0	25.0	35.7	10.0	25.0
• drought/ unreliable irrigation rationing	11.1	36.8	30.0	30.0	29.2	28.6	30.0	29.2
• Poor knowledge AWD/ SRI	11.1	5.3	10.0	0.0	6.2	7.1	5.0	6.2
• High weed infestation / several weeding rounds	0.0	15.8	0.0	0.0	6.2	10.7	0.0	6.2
• Time to refill the field	11.1	5.3	0.0	0.0	4.2	7.1	0.0	4.2

Table 4.11: Problems of water management as percentages of respondents in the surveyed area

Problems of water management$	Mlenge	Idodi	Madibira	Uturo	Iringa	Mbeya	Mean
• Climate change*#	36.7	87.1	83.3	80.0	62.3	81.7	71.9
• Poor irrigation infrastructures*#	73.3	83.9	30.0	10.0	21.3	80.0	50.4
• Unequal water distr.*#	70.0	38.7	26.7	36.7	54.1	31.7	43.0
• Lack of knowledge/skills on water management*	30.0	9.7	16.7	3.3	19.7	10.0	14.9
• Absence of water user associations	6.7	0.0	6.7	0.0	3.3	3.3	3.3
• Others[b]*#	26.7	9.7	3.3	3.3	18.0	3.3	10.7

[b]Combine unleveled farms/ field, siltation in water canals, water conflict, livestock encroachment
$More than one answer possible
*Significance difference among schemes at $p < 0.05$
#Significance difference between regions at $p < 0.05$

There are a number of factors that negatively affects soil health (Table 4.12) which included: lack of mineral fertilizers, soil degradation, and lack of knowledge on soil management. The farming system practiced in the study area is continuous rice cultivation. Such practice limits crops rotation and it ends up in nutrient mining due to less nutrient recycling. A significant proportion of the farm produce is sold to traders who come from other parts of the country. Crop rotation coupled with incorporation of crop residues after harvesting could be an alternative for nutrient recycling in such farming system. In this case, high usage of inorganic fertilizers is inevitable to such farmers. This could be the reason farmers perceive lack of inorganic fertilizers as challenge to their soils.

Table 4.12: Factors affecting soil health as percentages of respondents in the surveyed area

Factors affecting soil health[$]	Mlenge	Idodi	Madibira	Uturo	Iringa	Mbeya	Mean
• Lack of mineral fertilizers	36.7	32.3	30.0	53.3	34.4	41.7	38.0
• Unavailability of organic manures	20.0	9.7	26.7	23.7	14.8	25.0	19.8
• Land/soil degradation	26.7	35.5	50.0	26.7	31.1	38.3	34.7
• Climate change	26.7	32.2	23.3	13.3	29.5	18.3	24.0
• Lack of knowledge and skills on soil management	46.7	29.0	40.0	40.0	37.7	40.0	38.8
• Improper application/ rate and type	10.0	9.7	10.0	10.0	9.8	10.0	9.9
• Encroachment by livestock causing soil erosion	6.7	3.2	10.0	13.3	4.9	11.7	8.3
• Burning of crop residues	6.7	12.9	6.7	0.0	9.8	3.3	6.6
• Others[a]	6.7	12.9	6.7	3.3	9.8	5.0	7.4

[a]Combine Mono cropping , improper use of farm implements , right time for fertilizer application, water conservation, unleveled farms, continuous cultivation
[b]Combine unleveled farms/ field, siltation in water canals, water conflict, livestock encroachment
[$]More than one answer possible
*Significance difference among schemes at $p < 0.05$
[#]Significance difference between regions at $p < 0.05$

A small proportion of respondents (18%) use organic manure despite availability of cattle manure particularly in Mbarali district (Mbeya region). In other words, only 19.8% of respondents replied that unavailability of animal manure affects their soil negatively. The use of cattle manure in rice fields could help reduce problem of soil degradation and improve soil fertility. Some respondents claimed that the use of cattle manure would introduce new weed species and intensifies weed infestation which is the reason they shy from using it. We think that the problem here is lack of knowledge on how to prepare cattle manure. The findings of this study suggests that there is lack of knowledge on soil management among rice farmers.

Apparently, a large proportion of respondents reported to use inorganic fertilizers in their rice fields despite that they have mentioned lack of inorganic fertilizers to affect their soils. 95% of farmers in Mbeya region use more inorganic fertilizers whereas in Iringa 80.3% use inorganic fertilizers. Well-developed irrigation infrastructures in Mbeya, particularly Madibira, could be an attribute to high fertilizer use due to higher expected yields, hence income and ability of farmer to buy fertilizer. This can further be supported by our findings where in Mbeya region 78.9% of respondents apply fertilizer in splits (basal application and top-dressing) unlike in Iringa region where only 46.9% apply in splits and the rest apply only once. Actually, those practicing single fertilizer application are the ones who do not apply at planting, but they rather top-dress.

Majority of respondents reported to receive recommendation on fertilizer use from extension officers while a large proportion also copy from their fellow farmers. In recent years a number of agricultural development organizations train agro-dealers and use them to advise farmers on fertilizer use since they are the ones who meet farmers immediately before deciding which fertilizer to buy. This was not the case in the study area however only 11.5% of respondents received advise on fertilizer use from agro-dealers.

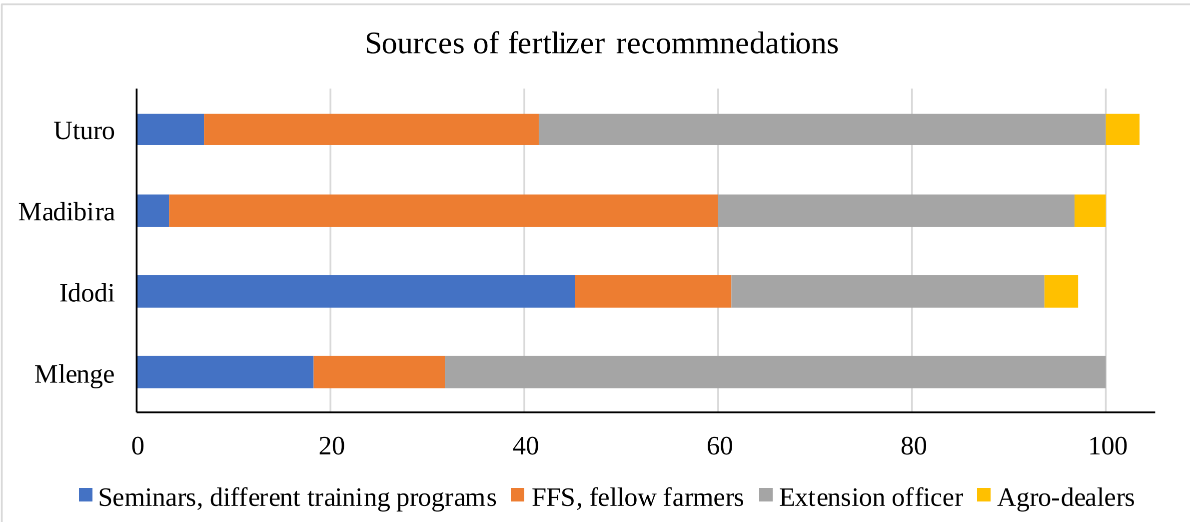


Figure 4.2: Sources of fertilizer recommendations (in %) as per respondents in the surveyed irrigation schemes.

With regard to soil testing, a good proportion (56.2%) of respondents are aware of the importance of soil testing , but only small proportion (11.8%) have tested their soil. The reason behind could be due to relatively high cost of soil testing which is not affordable to poor resource farmer. Another reason could be lack of knowledge on the procedures entailing soil sampling, handling and delivering to the laboratory. Conducting soil testing before using fertilizers is crucial in the context of climate change. It promotes efficient fertilizer use, nutrient management, carbon sequestration, reduced chemical inputs, adaptation to changing climate conditions, cost savings, and economic benefits. By integrating soil testing into agricultural practices, we can mitigate the environmental impact of fertilizer use, reduce GHG emissions, and contribute to sustainable agriculture and climate change mitigation efforts

Table 4.13: Application of fertilizers as percentages of respondents in the surveyed area

	Mlenge	Idodi	Madibira	Uturo	Iringa	Mbeya	Mean
Application of mineral fertilizers*#	63.3	96.8	96.7	93.3	80.3	95.0	87.6
Application modality*#							
Single	84.2	33.3	34.5	7.1	53.1	21.1	35.8
Splits	15.8	66.7	65.5	92.9	46.9	78.9	64.2
Application form*							
Separately	94.7	63.3	72.4	92.9	75.5	82.5	79.2
Mixing	5.3	36.7	27.6	7.1	24.5	17.5	20.8
Application boosters*#	15.8	3.3	0.0	0.0	8.2	0.0	3.8

Application organic manure	26.7	12.9	20.0	13.3	19.7	16.7	18.2
Planting legumes*#	3.3	25.8	0.0	0.0	14.8	0.0	7.4
Importance of soil testing	63.3	54.8	53.3	53.3	59.0	53.3	56.2
Tested soil	15.8	5.9	0.0	25.5	11.1	12.5	11.8

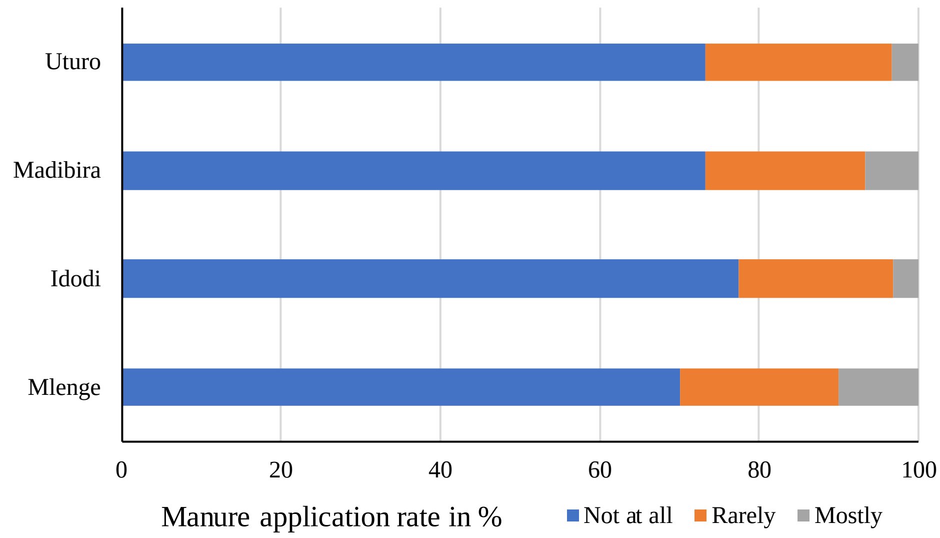
[a]Combine Mono cropping , improper use of farm implements , right time for fertilizer application, water conservation, unleveled farms, continuous cultivation
[b]Combine unleveled farms/ field, siltation in water canals, water conflict, livestock encroachment
[$]More than one answer possible
*Significance difference among schemes at $p < 0.05$
[#]Significance difference between regions at $p < 0.05$

Table 4.14: Main challenges of organic fertilizer application as percentages of respondents in the surveyed area

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
• Transportation cost *	46.7	19.4	16.7	23.3	26.4	32.8	20.0	26.4
• High Cost of fertilizer	13.3	6.5	6.7	16.7	10.7	9.8	11.7	10.7
• Not readily available[β]	16.7	12.9	30.0	40.0	24.8	14.8	35.0	24.8
• Lack of cash	3.3	0.0	6.7	0.0	2.5	1.6	3.3	2.5
• Lack of knowledge on proper use	13.3	16.1	13.3	6.7	12.4	14.8	10.0	12.4
• Renting of farms * [β]	3.3	19.4	3.3	0.0	6.6	11.5	1.7	6.6
• Drought/ delayed application/ scotching	3.3	3.2	6.7	0.0	3.3	3.3	3.3	3.3
• Increase weeds /insects in the rice field*	0.0	16.1	3.3	3.3	5.8	8.2	3.3	5.8

Table 4.15: Main challenges of mineral fertilizer application as percentages of respondents in the surveyed area

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
• High fertilizer cost	36.7	29.0	40.0	46.7	38.0	32.8	43.3	38.0
• Lack of capital	16.7	16.1	6.7	10.0	12.4	16.4	8.3	12.4
• Timely availability / transaction costs	20.0	19.4	13.3	20.0	18.2	19.7	16.7	18.2
• Poor knowledge on proper application*	33.3	16.1	36.7	6.7	23.1	24.6	21.7	23.1
• Fake fertilizer/ poor response	0.0	3.2	6.7	0.0	2.5	1.6	3.3	2.5
• Drought /water shortage	3.3	9.7	6.7	0.0	5.0	6.6	3.3	5.0
• Flood/repeated application	3.3	0.0	3.3	0.0	1.7	1.6	1.7	1.7
• Soil fertility status unknown	3.3	6.5	6.7	0.0	4.1	4.9	3.3	4.1



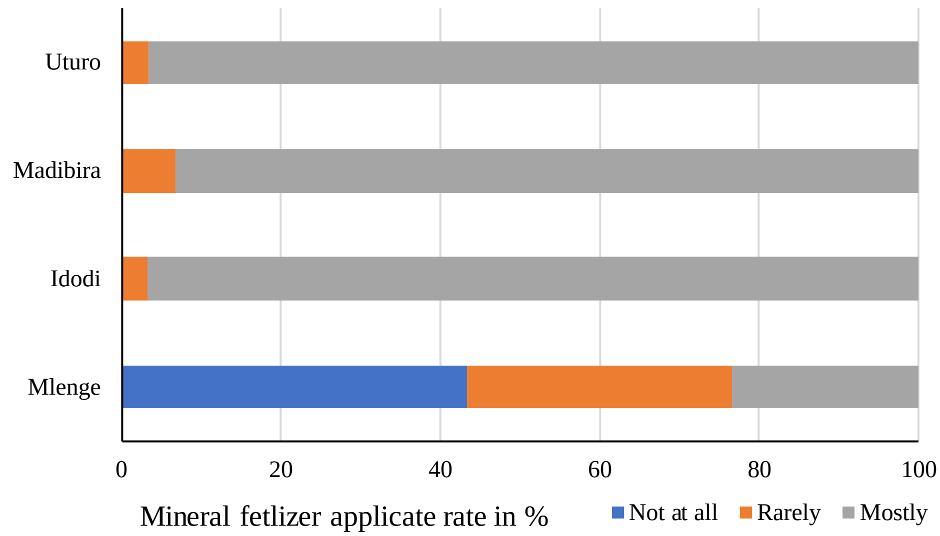


Figure 4.3: Manure and fertilizer application as percentages of respondents

Findings from this study indicated that there is a diverse application rates of fertilizers per unit area (Table 4.16). Madibira scheme in Mbeya region uses the highest rate up to 550 kg/acre while the lowest rate (25 kg/acre) was reported in Mlenge scheme, Iringa region. Types of fertilizers mainly used are Urea (46% N), DAP (18% N, 46% P_2O_5) and various blends of NPK. A blanket recommendation for N, P, K nutrients recommendation for rice farming in the two region is 40, 8, 8 kg/acre, respectively. Most of the respondents when asked, they admitted not to follow this recommendation but rather determine application rates based on yield response. This might not be economical and may be harmful to the soil and environment since some nutrients might be applied in excessive leading to nutrients imbalance. Here again comes the importance of judicial use of fertilizers based on soil test results.

Table 4.16: Application rates of mineral fertilizers (kg/acre)in the surveyed area

	Minimum	Maximum	Mean ± Standard error mean
Irrigation schemes			
Mlenge (n=19)	25.0	110.0	63.9 ± 7.09^a
Idodi (n=30)	50.0	300.0	132.5 ± 9.52^b
Madibira (n=29)	50.0	550.0	165.9 ± 20.2^b
Uturo (n=28)	100.0	200.0	129.5 ± 5.90^b
Regions			
Iringa (n=49)	25.0	300.0	105.9 ± 8.0
Mbeya (n=57)	50.0	550.0	148.0 ± 8.7

Values in each column bearing different superscripted letters are statistically different ($p < 0.05$, One Way ANOVA test) among schemes for A.
*Significance difference between regions (at $p < 0.05$, independent T-test) for B

4.4 Needs assessment in Rice value chain and Marketing

Local market is the dominant marketplace where much of the rice is sold. In Iringa respondents reported to sell milled rice which is value addition. The rice mills in this location are close to the rice production areas and farmers have some form of cooperatives particularly in Mlenge. On the contrary, none of the respondents in Uturo and Madibira reported to sell milled rice because traders buy directly at farm gate. Farmer to farmer sharing of market information were reported to be the most dominant form of information exchange followed by use of mobile phones. However, real time information is still lacking so changes in prices were not instantly communicated. Also lack of cooperatives in many areas limited the opportunity to link up well with markets. With the majority of farmers operating in isolation, most are forced to sell at farm gate. This means there is an urgent need to improve transparency among value chain actors and increase market information access.

During the survey, it was also observed that the weighing scales are not regulated and there is no standard weighing scale. Some use oversize buckets or un-calibrated weighing scale as well as lack of indicative of prices. In terms of rice marketing along gender lines, generally there was no big difference in the pattern of accessing the market and sources of information.

Table 4.17: Rice value chain and marketing aspects as percentages of respondents in the surveyed area

	Mlenge	Idodi	Madibira	Uturo	Iringa	Mbeya	Mean
Location selling paddy produce[$]							
• Farm gate to traders*[#]	36,7	16,1	66,7	63,3	26.2	65.0	45.5
• Farm gate consumers	10,0	0,0	6,7	6,7	4.9	6.7	5.8
• Local market*	70,0	38,7	70,0	53,3	54.1	61.7	57.9
• Distant market*[#]	10,0	48,4	0,0	0,0	29.5	0.0	14.9
• Rice at milling*[#]	53,3	35,5	10,0	0,0	44.3	5.0	24.8
• Paddy at warehouse*	10,0	35,5	16,7	10,0	23.0	13.3	18.2
Source of market information[$]							
• Friends/fellow farmers*	36,7	45,2	53,3	6,7	41.0	30.0	35.5
• Mobiles*[#]	30,0	58,1	26,7	6,7	44.3	16.7	30.6
• Radio	6,7	0,0	3,3	6,7	3.3	5.0	4.1
• Extension staffs	3,3	0,0	3,3	3,3	1.6	3.3	2.5
• Others[a]*[#]	80,0	61,3	86,7	93,3	70.5	90.0	80.2

[a]Combine brokers, buyers and millers; [$]More than one answer possible
*Significance difference among schemes at $p < 0.05$
[#]Significance difference between regions at $p < 0.05$

Table 4.18: Main challenges of rice value chain and marketing aspects as percentages of respondents in the surveyed area

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Iringa	Mbeya	Mean
• Lack of up-to-date market information and access to market outlets	40.0	35.5	53.3	46.7	37.7	50.0	43.8
• Absence of farmers organization for increased bargaining power	53.3	51.6	40.0	43.3	52.5	41.7	47.1
• Inadequate policy and institutional support to rice market	13.3	9.7	10.0	0.0	11.5	5.0	8.3
• Weak/absence of rice value chain actors	16.7	19.4	6.7	6.7	18.0	6.7	12.4
• Low price / price fluctuation	43.3	29.0	36.7	30.0	36.1	33.3	34.7
• Price determined by buyers /no indicative prices	20.0	22.6	6.7	23.3	21.3	15.0	18.2
• Improper weighing scales and methods/ oversize bags	10.0	12.9	6.7	0.0	11.5	3.3	7.4

[$]More than one answer possible

4.5 Innovation platform for SRI uptake

Agricultural innovations are considered as a technical package of practices, disseminated to farmers with the help of instruction, whereby the adoption rates representing a primary way of measuring their success (Hermans et al., 2021). Likewise, SRI – an agricultural innovation which require less agricultural inputs such as land, seeds, fertilizers pesticides and less water compared to conventional rice production – has been applied as option to maximize agricultural production, mitigate greenhouse gas emission, and enhance food security (Jain et al., 2014).

Understanding the importance of agricultural knowledge transfer and adoption, the current study assessed the level of SRI uptake by farmers and challenges that hinder its adoption in the study area. An overview of SRI awareness and practice (as percentage of respondents) in the surveyed area is presented on Table 4.19. Though no significant different was observed among assessed irrigation schemes and between the two regions. Many farmers (73 – 84% of the respondent) were aware of the SRI innovation, whereas extension officers (37.9%), training/workshop (28.4) and fellow farmers (33.7) being the major source of information about SRI. The results indicate a farmer-to-farmer extension services exists and somehow effective in the study area. Thus, the use of Training of Trainer (ToT) approach to coach few champion farmers to help disseminate SRI technology in their locality, will have a positive impact. On the other hand, the number of farmers attended SRI training in the study area was less compared to those knowing SRI, ranging from 30% to 71% with Idodi scheme having significant highest percentages. Most farmers received SRI training from NGOs (29.6%), extension officers (27.8%) and various projects (20.4%), whereas TARI researchers only mentioned 27.3% at Mlenge scheme and 22.2% at Madibira scheme.

The extension officers being among the major source of information and training of SRI, demonstrate a well-established and functional agricultural extension services in the study area. The extension officers have imparted the necessary SRI skills to the farmers, made available to them timely information, improved practices in an easily understandable form suited to their level of literacy and awareness. This means, involving extension officers in any project capacity development intervention activities, such as SRI Training, would have a great impact. In the existing practices the components that are deemed expensive include the uprooting young seedlings and short time span recommended between uprooting and transplanting, field leveling thus it the use of Mat nursery will simplify uprooting and machine transplanting will help to increase adoption and uptake.

These components mostly practiced by farmers in the study area, except for rotary weeding (up to 44.4 % of respondent at Mlenge scheme) and organic fertilizer (up to 21.1% at Idodi scheme). The results indicate most farmers who received SRI Training (44.6% of overall respondent), practiced SRI in their farm plot (39.7% of overall respondent). This means that the farmers' altitude level of putting into practice of what they learnt is high in the study area. It is important to note that the percentage of farmers practiced SRI was analyzed independently from those attended SRI training, in order to capture those who practiced SRI without receiving a formal SRI training, as observed at Madibira schemes – 30.0% received SRI training against 33.3% practiced SRI.

Farmers who practiced SRI in the study area were asked to identify the benefits of applying SRI innovation. High yield was mentioned by most farmers in all assessed schemes, ranging from 94 – 100% of respondents. Other identified SRI benefits were less water usage (12.5% overall respondents), few amount seed used (18.8%), many tillers (10.4%), and easiness of weeding (14.6%). The findings are in line with previous work on SRI by several researchers (Jain *et al.*, 2014; Geethalakshmi *et al.*, 2016). Further, farmers were asked to indicate their level of agreement on that assumption that "*Improving interaction of stakeholders and farmers through a learning process can enhance capacity for uptake of SRI practices"*. At least 90% of farmers supported the idea/assumption, most of them (74.4 % overall respondent) strongly agree. This means a positive turn out by farmers to attended SRI training in the study area is foreseen.

Table 4.19: SRI awareness and practice (as percentage of respondents) in the surveyed area

	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
Awareness of SRI	73.3	83.9	73.3	83.3	78.5	78.7	78.3	78.5
Source of SRI information$	(n=22)	(n=26)	(n=22)	(n=25)	(n=95)	(n=48)	(n=47)	(n=95)
Extension officers	45.5	34.6	40.9	32.0	37.9	39.6	36.2	37.9
Training/workshop*β	36.4	50.0	13.6	12.0	28.4	43.8	12.8	28.4
Fellow farmers/ demo trial*β	13.6	19.2	45.5	56.0	33.7	16.7	51.1	33.7
TARI researchers	9.1	0.0	4.5	4.0	4.2	4.2	4.3	4.2
Relatives/friends	9.1	0.0	9.1	8.0	6.3	4.2	8.5	6.3
Attended SRI training*β	36.7	71.0	30.0	40.0	44.6	54.1	35.0	44.6
Received SRI training from$	(n=11)	(n=22)	(n=9)	(n=12)	(n=54)	(n=33)	(n=21)	(n=54)
Project β	18.2	36.4	11.1	0.0	20.4	30.3	4.8	20.4
Champion farmer	0.0	0.0	11.1	8.3	3.7	0.0	9.5	3.7
Min. of agri. extension staff	27.3	18.2	44.4	33.3	27.8	21.2	38.1	27.8
TARI researchers*	27.3	0.0	22.2	0.0	9.3	9.1	9.5	9.3
NGOs	36.4	36.4	22.2	16.7	29.6	36.4	19.0	29.6
Others	27.3	31.8	0.0	50.0	29.6	30.3	28.6	29.6
SRI practice*	30.0	61.3	33.3	33.3	39.7	45.9	33.3	39.7
Component of SRI practiced$	(n=9)	(n=19)	(n=10)	(n=10)	(n=48)	(n=28)	(n=20)	(n=48)
Young seedling	77.8	84.2	40.0	80.0	72.9	82.1	60.0	72.9
Single seedling	88.9	68.4	70.0	60.0	70.8	75.0	65.0	70.8
Wider space	88.9	73.7	90.0	100	85.4	78.6	95.0	85.4
Rotary wedding	44.4	21.1	10.0	30.0	25.0	28.6	20.0	25.0

AWD	66.7	73.7	80.0	70.0	72.9	71.4	75.0	72.9
Org. fertilizer application	11.1	21.1	10.0	0.0	12.5	17.9	5.0	12.5
Mineral fertilizer application	88.9	78.9	90.0	90.0	85.4	82.1	90.0	85.4
Benefits of SRI$	(n=9)	(n=19)	(n=10)	(n=10)	(n=48)	(n=28)	(n=20)	(n=48)
High yield	100	94.7	100	100	97.9	96.4	100	97.9
Less water usage	22.2	10.5	20.0	0.0	12.5	14.3	10.0	12.5
Few amount seed used	22.2	21.1	30.0	0.0	18.8	21.4	15.0	18.8
Many tillers	11.1	0.0	10.0	30.0	10.4	3.6	20.0	10.4
Easiness of weeding	22.2	21.1	0.0	10.0	14.6	21.4	5.0	14.6
Level of agreement/ SRI uptake								
Strongly agree	76.7	77.4	70.0	73.3	74.4	77.0	71.7	74.4
Agree	20.0	19.4	23.3	16.7	19.8	19.7	20.0	19.8
Not sure	3.3	3.2	6.7	10.0	5.8	3.3	8.3	5.8

$More than one answer possible; *Significance difference among schemes at $p < 0.05$

$^{\beta}$Significance difference between regions at $p < 0.05$

Despites these benefits, partial or full-swing implementation of the components of SRI faces some challenges that hinder its wider adoption by many farmers in the study area, as depicted in Table 4.20. High associated cost, labor availability for SRI, farms not leveled, young seedlings can break easily, the risk of dying of the seedling and hence re-filling of several gaps, time consuming, and lack of knowledge about SRI are the major challenges of planting young seedling (Table 4.20), planting single seedling (Table 4.21), and planting wider space/in line (Table 4.22), mentioned by farmers. For successful implementation of these SRI components, promotion of preparation of modified mat nursery that produce 14 days young seedling that are healthy, relative long seedling with easy to transport and removal of seedlings compared to traditional nursery, as well as establishment of trained youth service provider groups for crop establishment activities (i.e., planting by space, in line/square, one seedlings per hill) to offset labor shortage. Farmers showed a concern that, planting a 14 days young seedling would easily be washed away by water in unleveled field. Further, poor field levelling and lack of water outlets from paddy fields were among the major challenges that farmer faces in implementing AWD. This means a concerted effort are needed to improve rice farm and irrigation infrastructure as a prerequisite for AWD irrigation which include farm leveling and lining of water canals and improvement in water outlet system.

Table 4.20: Main challenges of **planting young seedlings** as percentages of respondents

Challenges$	Mlenge	Idodi	Madibira	Uturo	Mean
• High cost*$^{\beta}$	44.4	5.3	0.0	0.0	10.4
• Extra labour required	0.0	5.3	10.0	10.0	6.2
• Labour availability for SRI*$^{\beta}$	0.0	0.0	30.0	10.0	8.3
• Time required to plant one acre	11.1	5.3	20.0	10.0	10.4
• Farms not leveled	55.6	31.6	30.0	20.0	33.3
• Young seedlings can break easily$^{\beta}$	11.1	15.8	50.0	40.0	27.1
• Drought /irrigation water rationing	0.0	21.1	10.0	0.0	10.4
• Lack of knowledge about SRI	0.0	10.5	30.0	20.0	14.6
• Participate in SRI training opportunity	100	96.8	100	100	99.2

$More than one answer possible for each challenge question

*Significance difference among schemes at $p < 0.05$

$^{\beta}$Significance difference between regions at $p < 0.05$

Table 4.21: Main challenges of **planting single seedlings** as percentages of respondents

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Mean
• High transplant costs	11.1	0.0	0.0	10.0	4.2
• Lack of labour	11.1	15.8	0.0	0.0	8.3
• Several gap filling	44.4	42.1	80.0	60.0	54.2
• Time consuming	0.0	10.5	0.0	10.1	6.2
• High incidence of seedling breakage	22.2	10.5	10.0	0.0	10.4
• Unlevelled fields [β]	0.0	5.3	30.0	20.0	12.5
• Low knowledge*	0.0	21.1	50.0	10.0	20.8
• Participate in SRI training opportunity	100	96.8	100	100	99.2

[$]More than one answer possible for each challenge question
*Significance difference among schemes at $p < 0.05$
[β]Significance difference between regions at $p < 0.05$

Table 4.22: Main challenges of **planting in wider spacing** as percentages of respondents

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Mean
• High transplanting costs	22.2	42.1	10.0	30.0	29.2
• Shortage of labour for planting	33.3	15.8	50.0	20.0	27.1
• High labour requirement	0.0	15.8	20.0	0.0	10.4
• Longer time to plant one plot	33.3	21.1	0.0	10.0	16.7
• Low knowledge and skills	22.2	21.1	10.0	0.0	14.6
• Participate in SRI training opportunity	100	96.8	100	100	99.2

[$]More than one answer possible for each challenge question
*Significance difference among schemes at $p < 0.05$
[β]Significance difference between regions at $p < 0.05$

Integrated pests management (IPM) and soil nutrients management using organic and inorganic fertilizer are among the practices promoted in SRI. Challenges related to these aspects, included high cost of pesticides and fertilizers, unavailability of pesticides and organic fertilizers, high weed infestation and poor knowledge on proper pests and nutrient management (Table 4.23). This means training on IPM and precision N management such as using rotary weeder/cono-weeder and leaf color charts (LCC) technology would substantially increase implementation and adoption of corresponding SRI components.

Table 4.23: Main challenges of **pest and diseases control** as percentages of respondents in the surveyed area

Challenges[$]	Mlenge	Idodi	Madibira	Uturo	Mean
Pest control					
• High cost	22.2	21.1	10.0	0.0	14.6
• Unavailability of pesticides	11.1	5.3	0.0	0.0	4.2
• Poor knowledge on application	22.2	10.5	10.0	20.0	14.6
• Drought / outbreak of insects	0.0	15.8	10.0	20.0	12.5
Disease control					
• High cost	11.1	5.3	10.0	0.0	6.2
• Poor knowledge on application	44.4	21.1	10.0	10.0	20.8
• Disease outbreak	11.1	15.8	0.0	0.0	8.3

[$]More than one answer possible for each challenge question

5 Conclusions

This study has identified the main knowledge gaps among the target groups (that include farmers, farmers organization, extension workers, researchers, and value chain actors) and ascertained the training and skills need in rice production focusing on SRI. Interviews and FGDs were carried out in the representative study irrigation schemes. According to the findings, the concept of SRI was not new for most of the groups who participated in the survey, but they lack knowledge and skills in implementing the basic SRI practices. Many farmers and extension officers had insufficient knowledge about planting in rows, use of young seedlings at 8 – 10 days, alternate wetting and drying irrigation using Panpipe and associated spacing. Farmers were not aware of using mat nursery that helps to ensure less seedling damage, easy uprooting and provide enough time for transplanting.

Several research findings have shown that SRI adoption contributes to high yield per unit area as compared to paddy cultivation. To increase adoption of SRI at farm level, institutional capacity building through customized trainings and field demonstration using simple and locally available materials are required, which is the main objective of work package 2 of this project. However, *large scale SRI adoption will require institutional and policy support for examples investments to improve irrigation infrastructures, access to machinery for field operations including land leveling.*

References

Alavaisha, E.; Tumbo, M.;Senyangwa, J.; Mourice, S. Influence of Water Management Farming Practices on Soil Organic Carbon and Nutrients: A Case Study of Rice Farming in Kilombero Valley, Tanzania. Agronomy **2022**, 12, 1148. https://doi.org/10.3390/ agronomy12051148

Aune, J.B., Nagothu U.S., Esser, K. and Tesfai, M. (2014) Opportunities for Support to System of Rice Intensification in Tanzania, Zambia and Malawi, Report commissioned by NORAD under the NMBU –Norad Frame Agreement, Noragric Report No. 71, ISSN: 1892-8102, http://www.nmbu.no/en/about-nmbu/faculties/samvit/departments/noragric

Babbie, E. (1990) Survey Research Methods. 2nd Edition, Wadsworth, Belmont.

Geethalakshmi, V., Tesfai, M., Lakshmanan, A., Borrell, A., Nagothu, U.S., Arasu, M.S., Senthilraja, K., Manikandan, N. and Sumathi, S. (2016). System of rice intensification: climate-smart rice cultivation system to mitigate climate change impacts in India. In: *Climate Change and Agricultural Development: Improving resilience through climate smart agriculture, agroecology and conservation* (eds. Nagothu, U.S). Routledge, Taylor & Francis Group, New York, USA. pp, 232 – 258.

Hermans, T.D.G., Whitfield, S., Dougill, A.J., Thierfelder, C. (2021). Why we should rethink ‘adoption’ in agricultural innovation: Empirical insights from Malawi. *Land Degrad Dev*.32:1809–1820. Ava. Online: https://doi.org/10.1002/ ldr.3833

Jain, N., Dubey, R., Dubey, D.S., Singh, J., Khanna, M., Pathak, H. and Bhatia, A. (2014). Mitigation of greenhouse gases emission with system of rice intensification in the Indo-Gangetic Plain, *Paddy Water Environment*,12, 355–363.ava. online: https://doi.org/10.1007/s10333-013-0390-2

Kahimba, F.C., Kombe, E.E. and Mahoo, H.F. (2014) The Potential of System of Rice Intensification to Increase Rice Water Productivity: a Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania Journal of Agricultural Sciences Vol. 12 No. 2: 10-19

Katambara, et al (2013) Adopting the system of rice intensification (SRI) in Tanzania, Agricultural Sciences, Vol.4, No.8, 369-375, ava. online at: http://dx.doi.org/10.4236/as.2013.48053

Materu, S.T. et al (2018) Water Use and Rice Productivity for Irrigation Mgmt Alternatives in Tanzania, mdpi journal Water, 10, 1018; doi:10.3390/w10081018

Mboyerwa, P.A. (2018) Potentials of SRI in climate change adaptation and mitigation: A review, International Journal of Agricultural Policy and Research Vol.6 (9), pp. 160-168, Available online at https://www.journalissues.org/IJAPR/https://doi.org/10.15739/IJAPR.18.018

MoA (Ministry of Agriculture) (2019). National Rice Development Strategy II

Nagothu, US., Nayak, AK., Tesfai, M. and Mohapatra, S.D. (2019) Technical Review of the System of Rice Intensification (SRI) initiative in Mbarali and Kyela districts of Tanzania

Reuben, P., Kahimba, F.C. Katambara, Z., Mahoo, H.F.,Mbungu, W., Mhenga, F. Nyarubamba, A. and Muyenjwa Maugo (2016) Optimizing Plant Spacing under the Systems of Rice Intensification (SRI), Agricultural Sciences, 7, 270-278 Online in SciRes. http://www.scirp.org/journal/as http://dx.doi.org/10.4236/as.2016.74026

Thiyagarajan T.M. and Gujja, B. (2013) Transforming Rice Production with SRI (System of Rice Intensification): Knowledge and Practice, National Consortium on SRI (NCS), pp 206

Toriyama, K. and Ando, H. (2011) Towards an understanding of the high productivity of rice with System of Rice Intensification (SRI) management from the perspectives of soil and plant physiological processes, Soil Science and Plant Nutrition, 57:5, 636-649, DOI: 10.1080/00380768.2011.602627

Annexes

Annex 1: Key recommendations on SRI development in Tanzania (source: Nagothu et al., 2019)

Soil and water management related to SRI	*Agronomy/crop mgmt. related to SRI*	*Extension related to SRI*
• Introduce water distribution through field channels and mobilizing farmers through Farmers Associations (FAs) to construct and maintain the irrigation structures	• Participatory seed production by linking the universities/ research institutions with FAs in the irrigation schemes to produce Quality Declared Seeds.	• Better practical training using improved demonstration plots/other front-line demonstrations (Result & action demonstrations) • Using ICT tools for improving knowledge exchange
• Install perforated plastic tubes (also termed field piezometer) to determine the right time of irrigating the fields	• Farmers to be encouraged for seed treatment before sowing with suitable fungicides	• Conduct exposure visits and targeted trainings on technical details of SRI
• Improve and upscale soil testing including micronutrients and need-based fertiliser recommendations based on soil test values	• Community nursey for participatory seedlings production, where a group of farmers within a FA can collectively raise nurseries nearby a water source	• Build capacity of NGOs like RUDI to better equipped them with knowledge and skills as promoters of SRI
• Improve timing and method of fertiliser application/ training and demonstration to farmers, agronomists and extension workers	• Introduce and use mechanical markers for planting in rows	• Promote private-public extension models using NGOs like RUDI to disseminate the SRI technology
• Improve soil fertility by adding organic fertilizers (e.g., farmyard manure, compost)	• Promote mechanical levelling with the help of tractor/power tiller /laser land leveller	• Provide regular weather-based crop advisory services
• Construct rain-water harvesting structures (e.g., community farm ponds) where water can be channelled to the command irrigated areas/ fields during scarce rainfall	• Introduce Integrated pest management (IPM)	• Involve agricultural academic institutions (like Sokoine University of Agriculture) in research and training
• Build in-field water harvesting structures (e.g., tied ridges, soil mulching, strong bunds in the SRI fields)	• Sensitize farmers on practicing crop rotation & crop residues management	• Improve stakeholder engagement through (e.g., multi-actor platforms) from the planning stage of the project

Annex 2: General comments and their components as identified by respondents

General comments category	Components
Farm and irrigation infrastructure	○ Farm leveling ○ Rehabilitation / construction of water canals
Infrastructure for rainwater harvesting	○ Construction of Charcoal dam/ for harvesting rainwater
Knowledge/ training of on rice farming	○ Better rice farming practices ○ SRI ○ Soil health ○ Proper application of fertilizer and agrochemicals ○ Awareness campaigns needed to every farm family ○ Give priority to rural people
Improved business environment for rice markets	○ Collective marketing ○ Indicative price for rice be given and known ○ Use of weighing scales ○ Construction of more warehouses ○ Rice milling machines
Agricultural implements	○ Friendly business environment /accessible loans for purchase of agricultural implements ○ Easy access to inputs esp. seeds fertilizers and agro chemicals ○ Lower cost of agro inputs
Improving research and extension service	○ There should be regular visit by research and extension officers during cropping season ○ Government to recruit more extension officers ○ Advisory of proper use of inputs (seeds, fertilizer and agrochemicals) ○ Soil fertility information availed
Views on SRI	○ SRI is good ○ Government make it mandatory for all farmers to adopt SRI ○ SRI is suited to climate change adaptation ○ Farm infrastructure not friendly for SRI
Acknowledgment	○ Government subsidies on fertilizer ○ Researchers visits to rural areas
Complaints	○ High water fees by Rufiji water basin (not affordable by farmers) ○ Timely solution to farmers problems ○ Farmers not given priority by government ○ Farmers are not protected by the government ○ Too many varieties confusing farmers

Annex 3. General comments of respondents on the challenges facing rice production in general in the survey areas and these are tabulated below

Challenges facing rice production in the surveyed area as percentage of respondents.

	Irrigation schemes					Regions		
	Mlenge	Idodi	Madibira	Uturo	Mean	Iringa	Mbeya	Mean
• Farm and irrigation infrastructure*$^{\beta}$	16.7	29.0	3.3	3.3	13.2	23.0	3.3	13.2
• Infrastructure for rain water harvesting	0.0	9.7	6.7	0.0	4.1	4.9	3.3	4.1
• Knowledge / training about rice farming*	56.7	29.0	53.3	26.7	41.3	42.6	40.0	41.3
• Improving rice business environment	16.7	22.6	30.0	20.0	22.3	19.7	25.0	22.3
• Agriculture inputs and implements*$^{\beta}$	43.3	25.8	20.0	13.3	25.6	34.4	16.7	25.6
• Improvement in extension services	10.0	12.9	13.3	10.0	11.6	11.5	11.7	11.6
• Views about SRI	3.3	3.2	3.3	0.0	2.5	3.3	1.7	2.5
• Acknowledgement	0.0	6.5	6.7	3.3	4.1	3.3	5.0	4.1
• Complaints$^{\beta}$	10.0	3.2	0.0	0.0	3.3	6.6	0.0	3.3

*Significance difference among schemes at $p < 0.05$

$^{\beta}$Significance difference between regions at $p < 0.05$