Peace Corps | West Africa

System of Rice Intensification (SRI)

Volunteer Handbook

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SRI Season Checklist

This checklist can be used to help keep track of activities while setting up and implementing an SRI trial. A more detailed planning guide is available in Section 2.2.

Activity	*Section*
3+ months prior to sowing	
☐ Preliminary meeting with community/counterpart to assess interest	2
☐ Assess if SRI is or has been done locally, how it was carried out, and what the results were	
☐ Determine what season to conduct your trial in	2.1
☐ Develop a plan for sourcing, aging, and incorporating organic matter	3.1
☐ Begin researching local rice production systems	
☐ Begin researching socioeconomic aspects of rice production and consumption	
1-3 months prior to sowing	
☐ Compost organic matter or age it in place in the soil	3.1
☐ Introduce the trial and SRI to local community leaders, government agents, etc.	2.3
☐ Identify counterparts/farmers who will be involved	2.3
☐ Provide training for counterparts/farmers (*ask Peace Corps Staff for training materials)*	Append. A
☐ Decide on a site location(s) and begin designing plot layouts	2.4
☐ Decide on a plant establishment strategy	3.2
☐ Identify available resources (weeders, markers, soil prep)	2.10 | 3.3.5 | 3.5.2
☐ Source or make any needed tools	Append. A
☐ Begin field preparation	3.1
☐ Decide on a rice variety	2.6
☐ Secure rice seeds if necessary	2.6
2-4 weeks prior to sowing	
☐ Inform local officials when and where trials will be held; invite them to attend events	2.3
1-2 weeks prior to sowing	
☐ Prepare nursery bed *(if applicable)*	3.3
☐ Flood trial plots *(if possible)* to sprout weeds, and then weed field before sowing	2.2
☐ Decide on row/plant spacing	3.3.1 | 3.4.3
☐ Make marking tools *(if necessary)*	3.3.6
1-2 days prior to sowing	
☐ Sort seeds using float test	3.3.4
☐ Germinate seeds for SRI plot	3.3.4
Seed sowing and beyond – in field for direct seeded rice; in nursery for transplanted rice	
☐ Carefully tend to nursery *(if applicable)*	3.3.5
☐ Prepare for transplanting – tools, supplies, training, etc. *(if applicable)*	3.3.6 | 3.3.7
☐ Invite local officials to attend transplanting *(if applicable)*	
☐ Plant establishment period: keep fields moist (as possible) for 2 weeks after transplanting/3 weeks after direct seeding, and avoid disturbance – only weed by hand	3.3.8 | 3.4.4
☐ Start mechanical weeding & intermittent watering after plant establishment *(if applicable)*	3.5

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Many of the concepts and ideas in this handbook were developed by SRI-Rice (www.sririce.org).

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Cover photo: Lorraine Perricone-Dazzo (Returned Peace Corps Volunteer, Senegal 2011-2013)
A rice farmer walks through her field in Senegal's Kaffrine region. As a PCV in the region, Lorraine worked to train farmers in SRI methods in 2012 and 2013, and conducted research on labor savings and yields associated with different seeding methods for rainfed SRI, which formed the basis for her master's thesis.

CONTENTS

Preface

This handbook was designed primarily for Peace Corps Volunteers in West Africa and their communities, but is intended to be applicable to other audiences as well – both outside of Peace Corps and outside of West Africa. The methodology it covers, the System of Rice Intensification, or SRI, is an adaptable strategy for ecologically increasing rice production while decreasing inputs, and with some local adaptation can be used in a wide variety of circumstances.

Introduction

Rice production and consumption patterns lie at the crossroads of many key aspects of rural, urban, and national economic and social development in West Africa:

- Agriculture is the foundation of many parts of West African societies and economies.
- One of the world's two species of domesticated rice, *Oryza glaberrima*, originated some 2,000-3,000 years ago in Mali's inland Niger River delta (Linares 2002).
- West Africa is the most important rice-growing region in Sub-Saharan Africa, accounting for 66% of all rice production—yet demand still far outstrips supply, causing the region to import up to 42% of its rice supply (***AfricaRice*** 2007), and rice imports alone to West Africa from Asia account for a full 20% of the global rice trade (OECD 2011).
- Rice imports take an economic toll on countries throughout the region: rice imports account for 16% of Senegal's balance of trade, and as of 2007 the country was producing only 20% of its demand (Government of Senegal 2010); in The Gambia, despite rice being the single most important staple crop, only 12% of demand is produced locally (Battaye et al. 2002); in 2012, Nigeria was the world's largest rice importer (FAO Stat 2014).
- Increased price volatility for imported rice, as seen in 2008, can lead to political pressure and social instability in the region (OECD 2011).

Despite all of this, average rice yields across the region have remained stubbornly low. In recent years there has been a widespread realization that massive rice imports are posing significant food security challenges in West Africa, and with this there has been a renewed interest in boosting domestic production (OECD 2011).

To overcome the shortfalls of earlier projects, however, successful efforts will almost certainly have to address some fundamental realities. In order to be equitable and sustainable, strategies to increase food production will need to protect environmental and human health, be accessible and economical for smallholder farmers, be gender appropriate, preserve or enhance biodiversity, and buffer against changing climates.

While there will certainly be no single solution that addresses all of these issues, SRI, or the System of Rice Intensification, shows promise and is particularly well suited for the realities of smallholder farmers. SRI is a dynamic and adaptive agroecological approach to increasing rice production while decreasing purchased inputs and allowing farmers to better utilize existing resources. While many agricultural development models rely on synthetic inputs, often in combination with modern crop varieties, SRI is primarily a knowledge-based management system, which can be used with any variety of rice.

As an agroecological methodology, SRI provides farmers with a simple, clear, and relatively immediate illustration of the benefits of holistic soil and plant management based on aerobic soils, fertilization with organic matter, and significantly reduced plant densities (80-95% fewer plants in most circumstances).[1] Despite the dramatic reduction in plants and the de-emphasis on synthetic inputs, yields typically increase by 30-50%, and in many cases 100% or more (Ly et al. 2012).

The key to SRI is a physical change in how the plants grow. Rice plants are highly adaptable, and given plenty of space and healthy conditions they can produce more or fewer shoots, known as tillers. Under favorable conditions, a single rice plant may produce 40, 60, or even more than 120 tillers – each of which can produce panicles heavy with grain. In conventional systems, where rice plants are typically

[1] Farmers in the region typically use 40-60 kg of seed per hectare when transplanting; SRI uses 6-8 kg of seed per hectare.

densely crowded, fields may be flooded, and seedlings linger for weeks in a tightly packed nursery, each plant may have only four or five tillers.

With aerobic and biologically rich soils, and less competition for resources, SRI management results in far deeper and broader root systems, making the plants sturdier, more efficient, and healthier overall. As a result, SRI fields are typically better able to resist pest and disease attacks, and withstand drought and severe wind or storms.

In addition to increasing yields and producing healthier plants, SRI is well suited for the working realities of Peace Corps Volunteers and their counterparts, and the goals and values promoted by the Peace Corps:

- Unlike development strategies that depend on external inputs, SRI is primarily a knowledge-based management strategy, so the means of increasing production (i.e., the knowledge) can more easily stay with the community after the Volunteer leaves.
- Because it boosts the inherent yield potential in any variety of rice, SRI can be used to preserve crop biodiversity and secondary traits (flavor, color, texture, ease of threshing/winnowing, straw quality, etc.) that are commonly found in traditional varieties but typically lacking in modern varieties (which often focus primarily on yield).
- SRI is fairly unusual among agricultural methodologies in that it both decreases overall greenhouse gas (GHG) emissions *and* increases the crop's resiliency vis-à-vis climate change impacts (Gathorne-Hardy et al. 2013).
- Due to the immediately visible differences between SRI-managed fields and conventionally managed fields, SRI shows quick and concrete benefits for farmers who fertilize with organic matter, incentivizing them to adopt more sustainable soil management practices.
- Wherever SRI adoption has spread, innovation and adaptation has been a farmer-led process and often results in an increased role of farmers as researchers, testing for adaptations that can maximize the benefits of SRI in their own conditions.

Along with the many potential benefits SRI brings farmers, it also presents challenges. Many of these are constructive, encouraging farmers to adopt more environmentally sound practices, but nonetheless there are hurdles to adoption that need to be addressed. Peace Corps Volunteers are uniquely suited to identify these barriers and collaboratively develop innovative solutions.

A planning checklist located on the **Inside Cover** can help you keep track of your activities. **Part 1** of this handbook will help you develop an understanding of what SRI is and how it works, so that you have the foundational knowledge necessary to be able to adapt SRI to local circumstances. **Part 2** outlines planning steps for setting up a comparison trial, and should be read well ahead of actually conducting a trial since some of the steps may need to be done several months in advance. **Part 3** is a technical step-by-step guide, walking you through the details of how to set up and carry out a field trial.

Appendix A includes additional SRI resources you may find helpful. **Appendix B** contains frequently asked questions (FAQs) about SRI. **Appendix C** is a comparison trial documentation sheet, to help you document details about the SRI trial plot and the conventional plot, and **Appendix D** can be used to compare the results of the harvest from each plot. **Appendix E** contains a list of references for information cited throughout this handbook. You'll notice many terms that are in ***bold italic*** throughout this handbook; these are defined in the glossary in **Appendix F)**. For Volunteers in Francophone countries, **Appendix G** contains a list of technical terms in French. **Appendix H** contains a list of calculations and conversions, including formulas for calculating the size of nursery beds, seed requirements, organic matter requirements, and yields.

Part 1 – Understanding SRI

Rice is grown in every country and in practically every agroecozone in West Africa, from the arid edges of the Sahara Desert in the north, down to the humid forests of coastal Liberia. Above, rice farmers in Mali's Timbuktu region show off their maturing rice crop, grown using SRI methods. (Photo: Erika Styger)

Part 1 – Understanding the System of Rice Intensification

The System of Rice Intensification, or SRI, is a management strategy for increasing rice production through the use of dramatically reduced plant density, non-flooded soils, careful attention to plant and soil health, and fertilization based primarily or exclusively on the use of organic matter such as compost or manure. SRI is not a prescribed package for farmers to simply take and apply. Rather, it requires an understanding of how field, soil, water, and plant management affect plant growth, and an often radical rethinking on the part of the farmer in terms of what actually is best for rice plants.

SRI practices work together in a synergistic manner, so partial implementation does not necessarily lead to a corresponding yield increase (i.e., the whole is greater than the sum of its parts). In order to really get the full benefit from SRI management, farmers must learn the principles behind SRI, and then identify how to adapt these to their local conditions in a way that allows them to most fully achieve the synergistic effect in a cost effective and practical manner.

Photos: Erika Styger

A focus on individual plant health (left), low plant density, grid spacing, and aerobic soils (right) are hallmarks of SRI plant and field management.

1.1 Principles and practices of SRI

No matter where or how SRI is practiced, it will follow the same four principles:

1. Early, careful plant establishment
2. Reduced plant competition
3. Biologically active soil, enriched with organic matter
4. Careful water and soil management to avoid flooding/drought stress during the ***vegetative growth phase***[2]

From these four principles, there are a number of practices that farmers can use to make SRI work best for them. Farmers are free to transplant from a nursery or to directly sow their seeds, for instance, and they are encouraged to experiment to find what works well, while seeking to maximize the synergistic effect.

SRI was first developed under irrigated conditions in Madagascar in the 1980s, in locations where farmers had complete ability to manage their water. Using similar conditions, these initial farmers used SRI with a common set of practices. As a result, SRI has in the past often been described as having six practices that were more or less fixed. However, as SRI has spread to other regions and other rice production systems, it's become evident that while SRI works in a wide variety of settings, local

[2] Terms in ***bold italics*** appear in the glossary in Appendix F.

adaptation requires rethinking these six practices, focusing instead on the core principles that make SRI work, and leaving farmers more free to adapt practices that will support these principles.

The table below shows a list of common practices that farmers can use to implement the four SRI principles. Note that farmers aren't limited to using the practices listed here and can also combine practices in different ways to support the four SRI principles.

SRI principles	Examples of related practices
1. Early, careful plant establishment	Seed sorting Seed treatment/pre-germination Careful raised-bed nursery management and careful transplanting at the 2-leaf stage (not applicable if using direct seeding)
2. Reduced plant competition	Only one seedling per hill[3] *if transplanting* One or two seeds per hill *if direct seeding* Wide spacing between plants (25 cm or more), using a square grid pattern (spacing is variable depending on conditions and variety used) Careful nursery preparation with low-density seeding and young transplanting to avoid leaving seedlings in a competitive environment
3. Biologically active soil, enriched with organic matter	Organic matter (compost, manure, green manure, etc.) is the primary source of fertility; synthetic fertilizers are used only if necessary ***Soil biological activity*** is enhanced through decreased tillage and/or use of ***cover cropping***, ***mulching***, crop rotations, compost tea, ***microbial inoculants***, etc. *(as possible)*
4. Careful water and soil management to avoid flooding/drought stress during the vegetative growth phase	Field ***leveling*** and ***bunding***, ***mulching,*** and organic matter applications are used to help retain soil moisture and rainfall, and allow fields to dry when necessary Flooding is prevented, particularly during the vegetative growth phase (for ***rainfed lowland rice***, this means timing your planting so that the vegetative growth phase occurs before or after periods of natural inundation; for irrigated rice this means only irrigating the fields periodically)

1.2 Synergy and the SRI effect

Under SRI management, plants grow larger, healthier, and more productive than under conventional management. A key reason for this is a rice plant's ability to change how it grows depending on its conditions. Individual shoots on rice plants are called ***tillers***. With good conditions, a single rice plant can produce over a hundred tillers, but under less ideal conditions the same plant may only produce a handful of tillers. The size and quality of the grain each plant produces also changes depending on the environment the plant was raised in.

Transplanting age and planting density are two of the biggest factors that affect the ***tillering*** capacity of a rice plant. Under optimal conditions, rice plants can produce new tillers at an exponential rate, but the period during which plants grow new tillers is finite. As with any exponential growth window, any

[3] In rice farming the term "hill" refers to a cluster of plants and doesn't mean that there is a physical height difference.

delays experienced at the beginning will dramatically decrease the amount of possible growth. Once this window has passed, the plant will shift its energy away from vegetative growth and toward reproduction (i.e., flowering and grain production). When plants linger in densely crowded nurseries for several weeks, this exponential growth window is largely missed.

The two images below illustrate this concept. On the left, 27-day-old seedlings sit in a nursery – each plant with just one tiller. On the right is a single plant that had been removed from the same nursery 11 days after sowing, and transplanted with plenty of space into a field rich in organic matter; 16 days later this plant had developed over a dozen tillers, while the plants still in the nursery have just one tiller each. The plants on the left and the one on the right are all the same age and the same variety, and the photos were taken on the same day.

Photos: Devon Jenkins

Densely planted nurseries and fields force rice plants to compete with one another for resources, including sunlight and soil nutrients. With little room to grow out – and few resources to support it – plants reach up to get more sunlight.

By contrast, SRI advocates early transplanting (though ***direct seeding*** is also possible), when the plants have only two leaves, which is generally about 8-12 days after germination. Each plant is also given plenty of space, and the soil is fertilized primarily with ***organic matter*** and kept ***aerobic*** throughout the vegetative growth phase. With plenty of time for tillering, lots of space, and rich and aerobic soil, the plants grow deeper and healthier roots, more tillers, more and larger ***panicles*** of grain, and larger and higher quality grain (Thakur et al. 2011).

Photo: Devon Jenkins

At right is a picture of the same rice plant from above, 16 days later (43 days after sowing) – now with 94 tillers. While this growth is a bit exceptional, it illustrates the point that with better plant management, farmers can more fully realize the genetic potential of the rice varieties they use, even without ideal conditions.

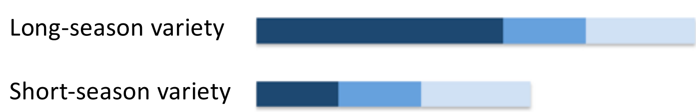
Farmers using traditional or conventional methods have good reasons for flooding their fields, transplanting older seedlings, and planting densely, though these practices carry unintended consequences. Since most terrestrial plants can't tolerate being submerged, flooded fields help farmers control weeds in an efficient manner. When fields are flooded, rice plants need to be transplanted at an older age so as to not be drowned, and since older seedlings have already lost most of their tillering potential, they need to be planted with close spacing to maintain high yields. While practical, these methods limit the health of the plants, suppress yields, and tend to require more external inputs like synthetic fertilizers, herbicides, and pesticides.

1.3 SRI management timing and rice growth phases

Rice plants have three primary growth phases – 1) the ***vegetative growth phase***; 2) the ***reproductive phase***; and 3) the ***grain filling/maturation phase***. The primary purpose of SRI is to change the growth pattern and shape of the plants, which is only possible during the vegetative growth phase. Once this phase is over SRI management no longer applies, and farmers are free to follow whatever practices they choose to, including flooding their fields if they choose to.

Different rice varieties have different season lengths, meaning that the time from germination to harvest varies. "Long-season" varieties often take up to 5 months (and as much as 1 year!) to germinate, grow and ripen, whereas "short-season" varieties may take less than 3 months to complete their whole lifespan. Both the reproductive phase (≈ 30 days long) and the grain filling/maturation phase (≈ 40 days long) are relatively fixed in terms of duration though, regardless of what rice variety is being grown. This means that the entire difference in the length of the cropping season for different varieties of rice happens during the vegetative growth phase, which can last from a few weeks to many months (Moldenhauer and Slaton 2001).

In the representations below, the length of the vegetative growth phase (in dark blue) varies greatly between the long- and short-season varieties, while the reproductive phase (in medium blue) and the maturation phase (in light blue) are essentially the same length for both varieties of rice.



For SRI this means that since a short-season variety will have a much shorter vegetative growth phase than a long-season variety, the amount of time under SRI management for this short-season variety will also be reduced in comparison to a long-season variety. With less time under SRI management, SRI tends to produce less dramatic changes to plant growth for short-season varieties.

1.4 Overcoming constraints

While SRI works across many different rice cropping systems, there are typically challenges that have to be addressed, including water, weed, soil, and labor management. More detail on many of these issues is presented in Part 3 of this handbook.

Managing water

SRI requires aerobic soil during the vegetative growth phase to ensure healthy ***soil microbial activity***, and to maximize both root growth and tillering. Once the vegetative growth phase is over, and plants start flowering, farmers can return to their normal crop management practices.[4]

For farmers with full water control (typically seen with irrigated rice) this means simply watering their field on an as-needed basis during the vegetative growth phase, and allowing the soil to dry out a bit between each watering. For farmers in rainfed upland systems, water management is more a matter of

[4] Note that during the ***grain filling stage***, shortly before maturity, rice plants do need extra water to ensure that the grains are filled properly.

maintaining soil humidity through bunding, leveling, incorporation of organic matter, and perhaps mulching.

Keeping soils aerobic mostly becomes a problem for farmers in rainfed lowland conditions, where seasonal flooding can be difficult or impossible to avoid. Despite these challenges, farmers have options for practicing SRI, such as: moving the cropping season forward so that the vegetative growth phase finishes up just as the fields become inundated; switching to dry season farming if irrigation water is available; or choosing a site slightly higher up the slope (***toposequence***), where plant roots may have access to ground water, but will still be largely in aerobic conditions. Some sites will be more readily favorable to SRI management than others, but farmers will see benefits in almost any circumstance, even if implementation is partial.

In most rice systems, there are secondary management options that can help maintain good soil moisture levels, such as bunding, leveling, mulching, and adding organic matter to the soil. More details on all of these management strategies are presented in Sections 3.1 and 3.5.

Managing weeds

In non-flooded systems weeds can be a challenge. Farmers can use technology they already have, like hand hoes, to weed between plant rows. However, this is time consuming and laborious and is often impractical for larger plots. To speed this up and save energy in the process, simple mechanical weeders can be purchased or built, but in West Africa few of these are currently available. Furthermore, different soil and water conditions demand different types of weeders. Lack of a vibrant and effective market for weeders across the region is a significant bottleneck for SRI development, but is one that is increasingly being addressed. More information on weeders is presented in Section 3.5.

Starting seedlings in a nursery and transplanting can be part of an effective strategy to control weeds, but isn't practical for many farmers due to weather challenges or labor constraints. In places where it is practical, farmers can water and weed their field right before transplanting, which gives the newly transplanted seedlings a head start over any new weeds that will sprout.

For farmers for whom direct seeding makes more sense than transplanting, the weed seeds and rice seeds will begin sprouting at essentially the same time, meaning that the rice plants will not enjoy a head start, beyond potentially being pre-germinated prior to seeding. Because of this, direct-seeded systems face more pressure from weeds, and farmers need to be much more aggressive in weeding their fields early and frequently at the start of the season. In some situations, farmers may be able to wait to plant until after the first few rains and remove any weeds that have sprouted prior to planting their rice.[5] Combining SRI with other agroecological methodologies, like Conservation Agriculture, can help address weed issues through the use of mulching, crop rotations, and zero (or minimal) tillage.

Managing soil organic matter

For many farmers in West Africa, adding organic matter to their soil is either an afterthought, or something they aren't very used to practicing. Throughout much of the region, farmers have historically practiced variations on a form of long fallow or rotational cultivation called swidden agriculture, or 'slash and burn.' In traditional systems like these, forests are cut and burned, then crops are planted for up to a few years, after which they are left to regrow while the farmer starts over with a new piece of forest. The fallow during which the forest regrows can last decades, allowing the soil to recover. In tropical environments with low population densities, swidden agriculture can be very

[5] One additional advantage of SRI is that it typically shortens the rice cropping season by 1-2 weeks, which may make this delay more feasible for some farmers. Typically, however, rainfed upland farmers prefer to get their crop in the ground as early as possible in case the rainy season ends earlier than expected.

sustainable if a small portion of the land is being farmed, and if fallow periods last a long time. However, as the population increases and fallow periods decrease, the soil becomes less capable of recovering. Currently many farmers now cultivate the same plots year after year, but without a strong cultural history of managing soil fertility for permanent cultivation, their plots are in danger of being worked unsustainably. Simply explaining to farmers that organic matter is important is often not enough to convince them to adopt a different behavior. SRI provides an entry point for demonstrating how beneficial organic matter can be.

By conducting a small side-by-side demonstration plot that compares SRI management with conventional/traditional management, farmers typically will be able to see a clear contrast in the health and performance of the plants and draw conclusions for themselves about the importance of organic matter in the soil. Once this recognition is established, they'll be more likely to seek out sources of organic matter for themselves – instead of being told they need to do so.

One major constraint with organic matter is competing demands. In many parts of West Africa, there are multiple demands placed on virtually any accessible organic matter, typically for animal feed or fuel. These competing demands can exist within a household, between households, or even between groups practicing different land uses (herders and farmers, for instance). Furthermore, where rice is not the principle crop, farmers may prefer to divert organic matter to other crops.

Sources of organic matter are all around: animal manure, weeds (that should be composted before using), stubble and residue from rice and other crops, household food waste, waste streams from crop processing (sugar cane bagasse, rice husks, peanut waste, etc.), and so on. When competition for scare organic matter resources is high, explore options for generating more organic matter by using ***relay crops***, ***green manure***, ***cover crops***, agroforestry crops, or ***companion plants***. Penning animals in a field or using integrated systems (where organic matter streams, such as manure, flow from one part of the system directly into another part of the system) are other options as well. In many cases, more organic matter can be found simply by reducing the amount that is lost. When farmers burn their fields during the dry season, the carbon in the burned plants is lost into the atmosphere and contributes to greenhouse gas emissions instead of being returned to the soil in the form of compost or manure (if eaten by animals).

<u>Managing labor time/costs</u>

SRI often changes the timing and nature of certain aspects of the labor involved in rice production. As with other aspects of SRI management, how it affects labor practices varies greatly depending on local conditions. In some places SRI reduces labor costs, in other places it increases them.

Often labor costs go up initially, then decrease with time, as farmers become more habituated to SRI. For farmers that already transplant, SRI transplanting can at first take more time than what they're used to, but after some experience they many find it ends up taking less time than conventional practices. Some field preparation methods, such as leveling, take extra time to prepare the first time, but far less time to maintain after the initial effort.

For other aspects of SRI management, labor can often be more time consuming. For farmers who give up irrigation for mechanical weeding, this is almost certainly the case – however, mechanization or mulching can reduce the time, energy, and money used for weeding. In any case, farmers should continuously experiment to find ways to reduce labor demands and increase their ability to maximize the benefits of SRI in a cost-effective and easy-to-use manner. In cases where labor costs increase, farmers should calculate out the cost/benefit of SRI to see if any revenue gains from increased yields compensate for added labor costs.

Timing of labor can also change under SRI management, both within a season and between seasons. Under SRI, transplanting happens earlier than for traditional or conventional systems, and weeding becomes a new time commitment for some. Field preparation, including sourcing and preparing organic matter, can add extra work between the growing seasons, and farmers may even shift their rice production to a different season entirely. Therefore, it's crucial to be aware of how other commitments can affect farmers' ability to implement SRI. Analyzing farmer labor calendars in your community can help give you a better understanding of potential conflicts and opportunities.

Transplanting, in particular, is more time sensitive under SRI than for traditional practices. Farmers are typically able to leave their plants in the nursery until conditions permit, even if this takes a month or more. With SRI, however, the plants must be transplanted at the two-leaf stage, making it more challenging and imperative to carefully time for weather conditions and field preparation needs.

Even if farmers have a difficult time fully implementing SRI, they can still benefit from SRI practices such as fertilizing with organic matter and leveling and bunding their fields. Similarly, SRI can act as an incubator for technological development. When farmers see a means of sustainably increasing their yields and resilience, they will search out ways to remove the bottlenecks that prevent them from taking this to a larger scale. The technologies they identify or develop can lead to other innovations and benefits in their lives.

1.5 Ideal versus practical implementation

SRI represents a set of ideal principles that, if well executed, can dramatically improve plant growth and yields from any variety of rice. However, there is often a fairly large gulf for farmers between the ideal scenario and what's practical. Volunteers should aim to find a balance that's practical for farmers, while still trying to maximize the positive effects from SRI management.

Part 2 – Planning Guide

SRI is about producing more with less, making the best use of what farmers already have access to, and continuously experimenting to identify new innovations and adaptations. Above, a farmer brings part of his nursery to the field to transplant. (Photo: Erika Styger)

Part 2 – Planning an SRI trial with your counterpart

If you and your counterparts will be the first in your community or even region to try SRI, then it's imperative to start with a demonstration trial to establish validity of SRI for people who are not familiar with it. This experimentation also provides key information about how to adapt practices to local conditions. A well-executed trial can generate lots of interest and enthusiasm, but a poorly executed trial can lead to negative associations which could be hard to shake, even years down the road. To ensure success, start small, and plan things well. Conduct a side-by-side trial of SRI and normal farmer practices, make both plots the same size, and start the seeds on the exact same day.[6] Use the same variety of rice for each plot – ideally a variety that farmers are already familiar with, otherwise farmers may misinterpret the results as being due solely to a new variety.

Plan every step in close collaboration with your counterpart. Make efforts early on in the planning and throughout the execution process to involve the community, local extension workers, community leaders, local government officials, and other curious farmers.

With SRI, timing is crucial. Read through this manual before you start planning any details of the trial, and create a calendar to track each step – the [SRI Trial Planning Worksheet in Section 2.2 can help]. Take detailed notes in a journal, and track every step. SRI will need to be adapted to your local conditions, but to do this you'll need to have a record of what is done at each step of the process. If your counterparts are not already familiar with doing agricultural experimentation, then this process could be a chance to develop skills and practices that may have a lasting, beneficial impact beyond rice production.

Photos: Devon Jenkins

With aerobic, organic matter-enriched soils and early transplanting, plants can easily fill extra space.

[6] Even if you use different plant establishment methods for the two plots, such as direct seeding and transplanting, make sure to start (germinate or sow) the seeds at the same time.

2.1 Seasonal timing

Assess local conditions to determine the season or time of year to conduct your trial. Water availability is often a primary consideration, followed by factors like labor availability, farmer interest, traditional practices, weather patterns, and other crop cycles.

In most cases, you will want to conduct your demonstration trial concurrently with the primary rice growing season. In some cases, however, this won't be practical or even possible.

For fields that lie in a lowland floodplain or depression that will fill up with water during the rainy season with little or no option for drainage, SRI becomes difficult to do during the normal planting season, given that aerobic soil management simply can't be practiced. In some cases, farmers may be able to practice SRI on fields that are slightly above the flood zone, while in other situations they may be able to experiment with shifting the cropping season.

Because SRI only affects water management during the vegetative growth phase, once the reproductive phase starts farmers are free to follow whatever means of water control they prefer or have access to, including flooding or continuing with aerobic soil management. If you have year-round access to water (whether from irrigation canals or access to ponds or rivers), then it could be possible to grow a trial SRI crop entirely in the dry season, or to start your SRI trial toward the end of the dry season, timing it so the rice finishes the reproductive phase around the time the plots begin to fill with water (i.e., when aerobic soil management is no longer necessary).[7]

In the interest of keeping things as easy as possible for a first trial (and minimizing risk of things going poorly), it's often best to set up a controlled environment, even if that doesn't perfectly reflect conditions most farmers face, using a small plot with reliable access to water but no threat of flooding. In consultation with your counterpart, weigh the potential downsides of this approach with the potential benefits.

2.2 Planning timeline

Developing a good plan is simple and will make your trial easier, smoother, and more likely to be successful. If it helps, make a simple spreadsheet listing the supplies you'll need and what activities you'll need to do for each step. Review this with your counterpart and a local extension agent (if possible), and then draw up a calendar. You can also use the following SRI Trial Planning Worksheet to help develop a plan. The checklist on the inside cover can be used to help keep track of each step, and has references to help you quickly find relevant information within this handbook.

[7] There are other reasons as well to consider growing rice during the dry season, if possible. Farmers in Liberia have experimented with shifting the cultivation to the dry season to facilitate doing SRI – with a partially unintended side benefit. During Liberia's rainy season, clear skies are rare, limiting the photosynthesis plants can do and suppressing yields. By moving rice production to the dry season, farmers are not only able to better practice SRI, but can gain the additional yield benefit that sunnier weather brings.

SRI Trial Planning Worksheet *Write dates in this column:*

<table>
<tr><td>Trial start date
(write in the date you anticipate germinating or sowing the seeds)</td><td>*Planned start date (germination/sowing):*</td></tr>
<tr><td>To do **3 months** or more before sowing:</td><td>*Start date minus 3 months:*</td></tr>
<tr><td colspan="2">

- Identify if any other SRI trials have been done in the area, who did them, and what the results and perceptions were.
- Determine an organic matter source (or sources), how much will be needed, and how it will be decomposed/composted. Draw up a calendar to make sure you have enough of it in the ground at the right time (see Section 3.1).
- Begin researching the local rice production systems and agroecological zones, keeping in mind that each locality can have many different systems, sometimes right alongside each other – talk with farmers, extension agents, your technical resources at post, and NGOs.
- Begin researching the economic, social, and cultural aspects of rice production and consumption in your area. Include: rice-related labor divisions (in terms of gender, age, and class); the seasonal labor calendar; where locally produced rice is sold, how much income is generated, and who controls this income within the family; how and where rice income is used (e.g., to pay school fees); any special social or cultural significance rice has; how rice compares to other crops or livelihood activities (livestock, gathering, market vending, formal/informal labor, etc.) in terms of economic and food security importance; and the history of local rice production.

</td></tr>
<tr><td>To do **1-3 months** before sowing:</td><td>*Start date minus 1-3 months:*</td></tr>
<tr><td colspan="2">

- Introduce the concept of an SRI trial to local community leaders, farmers, NGOs, local politicians, and extension agents, and keep everyone informed at each step of the process.
- Identify the counterpart(s) you'll be working with, and any extra labor that may be needed.
- Decide on a site location.
- Decide on a plant establishment strategy – typically either transplanting from a nursery, or direct seeding (see Section 3.2).
- Identify what tools and resources you have available in your region – items such as weeders (***rotary weeders***, hoes, motorized weeders, animal-drawn weeders), land preparation tools (plows, tractors, rototillers, animal drawn equipment, hand equipment), transplanting markers, irrigation pumps, etc.
- Decide on what rice variety to use, and secure seeds if necessary (typically it's best to start with a variety that is already commonly used in the area).
- Begin field preparation, including potential leveling, bunding, and puddling (see Section 3.1).

</td></tr>
<tr><td>To do **2-4 weeks** before sowing:</td><td>*Start date minus 2-4 weeks:*</td></tr>
<tr><td colspan="2">

- Inform local officials when and where you'll be starting the trial, and invite them to attend milestones in the trial process by making them public events.
- Finish field preparation.

</td></tr>
<tr><td>To do **1 week** before sowing:</td><td>*Start date minus 1 week:*</td></tr>
<tr><td colspan="2">

- Prepare your nursery.
- Flood your fields (if possible) to sprout any weed seeds in the soil, then weed before sowing (if you are planting your seeds directly in the field) or transplanting; this gives rice plants a head start in a relatively weed-free setting.
- Decide on spacing.

</td></tr>
</table>

<table>
<tr><td colspan="2">

- Make or procure any necessary marking tools (e.g., rake, roller, or marked rope), and practice using them ahead of time (see Section 3.3.6)

</td></tr>
<tr><td>To do **1-2 days** before sowing:</td><td>*Start date minus 1-2 days:*</td></tr>
<tr><td colspan="2">

- Sort your seeds to choose only the most completely filled grains (see Section 3.3.4)
- Germinate your seeds for the SRI plot, to ensure uniform plant establishment.

</td></tr>
</table>

(Sowing – In nursery for transplanted plots, or in the field for direct-seeded plots)

<table>
<tr><td>To do **within 1 week** after sowing
(for plots that will be transplanted):</td><td>*Start date plus 1 week:*</td></tr>
<tr><td colspan="2">

- Make sure all preparations are ready for transplanting, including supplies, labor, camera for documenting, marking tools, etc.
- Invite farmers and local officials to participate in the transplanting process.
- Observe the nursery closely, and be prepared to transplant when the plants reach the two-leaf stage (typically 8-12 days after germination).

</td></tr>
</table>

(Transplanting – If applicable)

<table>
<tr><td>To do **1 month** or more before harvest:</td><td></td></tr>
<tr><td colspan="2">

- Plan a harvesting strategy with your counterpart to ensure you collect the data you'll need to analyze your results.
- Plan a harvest festival, inviting farmers and local officials to attend and discuss the trials.

</td></tr>
</table>

2.3 Materials

A few basic and easily accessible supplies will help you carry out a successful demonstration plot:

- A **digital camera** – one that can geo-tag photos is great, but not necessary
- A **measuring tape** – often available in markets or hardware stores, or at a school
- A **notebook** and **pencil –** for recording a trial log
- A **scale** – for measuring seed at the beginning of the trial, and for harvest (see Section 3.6)

Agronomic supplies include:

- **Rice seed**, of a variety that you choose with your counterpart/community
- A **marking system** – a rake, measured/marked rope, roller, or other system (see Section 3.2)
- A **mechanical weeder** (if available in your area) – ideally you can compare multiple weeder types to see which works best for your local conditions (soil, labor, gender considerations, etc.)
- A small **weeding hoe** – if no mechanical weeder is available
- A larger **hoe** (daba) – for field and nursery bed preparation
- A gardening **rake** (optional) – for preparing nursery beds and demonstration plots
- A large **wooden board** – for leveling the plot
- **Organic matter** – this can be manure, compost, green manure, or crop residues; for details on what kinds to use, how much to apply, and how it should be decomposed, see Section 3.1

For inspiration and ideas concerning SRI-specific tools and equipment, visit the following sites:

- Compilation of SRI tools by the Watershed Support Services and Activities Network (WASSAN): www.wassan.org/sri_implements/
- SRI Equipment Innovators Exchange Facebook group: www.facebook.com/groups/SRI.innovators

2.4 Engaging the community and identifying collaborators

There are many ways to engage your community in your SRI trial. For example, screening a video ahead of time can be a good option. Links to SRI videos available online can be found at http://sri.cals.cornell.edu/videos and www.sriwestafrica.org/resources/, or by searching YouTube for "System of Rice Intensification." The set of SRI videos by Flooded Cellar listed in Appendix A are very well done, and work well for this context.

Look for local organizations that are already involved in SRI, and make connections with someone in your country or region who has some experience with SRI. See if they are interested in getting involved or sharing their experiences. You can find out more about local organizations that are active in SRI across the region by visiting http://sri.cals.cornell.edu/countries or www.sriwestafrica.org/countries. The SRI West Africa Facebook group, www.facebook.com/groups/sriwestafrica, can also be a good resource for finding local practitioners.

2.5 Identifying and laying out a site

Trial site selection is important, and a well-chosen site has many benefits, including:

- Great visibility, which can spark interest in your trial within the broader community and from passers-by
- Conditions that are representative of what most local farmers can relate to, encouraging greater acceptance and participation from neighboring farmers

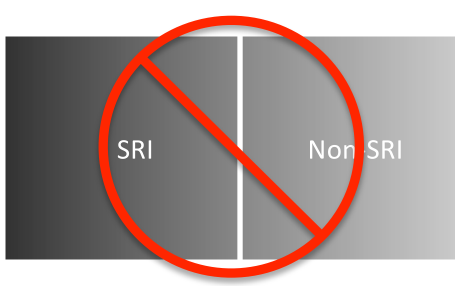
- Easy access for the entire duration of the trial, without barriers from flooding, road construction, etc.
- Reliable, easy access to water if that's part of your trial design – make sure to think through potential challenges and identify contingency options in case things fail
- Proximity to where you and your counterpart(s) live, so that ideally no one has to travel too far
- An ability to get materials there easily, including transportation infrastructure– consider how you'll get compost, manure, and tools to the site
- Lack of extreme slope, where possible – moderate or slight slopes can be fairly easily accounted for by dividing the area up into smaller plots (squares or strips) and doing some basic terracing and leveling, but steeper slopes are far more difficult to work with

Good control of gradients is another important consideration, particularly between the conventional and the SRI plots. Factors like slope, depth of water table, seasonal flooding, and soil quality can affect plots differently, so make sure your plots experience the same conditions, as much as these are part of your trial's design. (If, for instance, rainfed lowland rice is traditionally inundated in your area, but you'll be comparing this to SRI plots grown slightly above the inundation area, then this would be an instance where the plots would differ from each other.)

If the plots are adjacent, check for any apparent gradients and adjust the design accordingly. The diagram at right, for example, depicts a gradient in soil color across the plot, indicating a likely difference in soil composition, and potentially soil fertility

Regardless of what is causing the gradient – differences in soil fertility, depth of water table, etc. – if it could affect the performance of the trials, then both the SRI and conventional plots should be oriented to experience this gradient in the same manner. To do this, you could either design a checkerboard block pattern, or create two rectangular plots side-by-side, making sure the alignment runs in the same direction as the gradient:

Do not, however, arrange your plots so that the SRI and non-SRI plots have different conditions:



2.6 Sizing your plots

The best advice for a first trial is to start small; when trying something new, it's important to set ourselves up for small successes.

Starting with a large SRI plot can be overwhelming, and if farmers fall behind in weeding, then the rice plants and the yields will suffer. By starting small, farmers can increase their area under SRI as their confidence, skills, and techniques improve.

Ideally, keep the SRI and conventional plots to the same exact size and dimensions. There's no fixed rule, but 10m by 10m (100m^2) is a good target size for each plot, and makes yield conversions easy, since one hectare is 10,000m^2. Plots larger than 20m by 20m (400m^2) aren't recommended for a first trial, and plots smaller than 10m by 10m are essentially too small to be valid demonstrations.

2.7 Choosing a rice variety

SRI management affects all rice varieties in the same manner, though not to the same extent. When trying SRI for the first time, it's generally important to focus primarily on establishing the validity of the methodology. Therefore, choose a variety that is locally used and well known by farmers, and make the decision in collaboration with your counterpart. Once SRI is better understood, it's easier to focus on determining which varieties respond best to SRI under local conditions. Some factors to consider include whether a variety is known to have a high capacity for tillering, and the variety's season length. Varieties that don't tiller well will not respond as well to SRI. Season length determines the length of the vegetative growth phase of a variety – which is the time period in which SRI management affects plant growth. A longer season length will allow more time for tillering, and thus will work better for SRI.

2.8 Working with multiple variables

There shouldn't be much need during an initial trial to include multiple variables, as the primary goal is simply demonstrating SRI versus conventional practices. After this first trial, however, when you and your counterparts have a feel for SRI, consider planning trials with several variables. Potential options to choose from include: spacing, variety, types and application rates of organic matter, weeding methods, and watering frequency.

When testing multiple variables, remember that SRI relies on a synergistic effect to change how plants grow. If you use all the principles together you get a disproportionately greater impact than if you isolate a subset of the principles – so as much as possible, aim to include all the principles in your experimental design, and figure out how farmers can formulate practices that best enable them to apply these principles in the most cost-effective and rewarding manner given their local conditions.

2.9 Keeping track of and sharing your data

While it's often the last thing on your mind when you're first getting started, it's important to plan for data collection from the very start. Without data from previous trials, it can be difficult or even impossible to replicate past successes, or to determine how best to adapt SRI to your local conditions. In other words, data collection enables you to create a feedback loop to adapt SRI and improve your rice production. Furthermore, when data is recorded it can then be shared, allowing farmers in your area and in similar climatic zones around West Africa to benefit from your experience.

Trial logs are excellent ways to keep track of all your data. Use a specific notebook just for your trial, and write down dates for every activity, using pencil if possible (ink can run if it gets wet).

Data can include measures of variables that affect plant growth (such as spacing, watering frequency and duration, variety selection, weeding frequency, weeding method, weather, nursery conditions, presence of weeds, pests or diseases, fertilization), and indicators of plant growth and performance (such as tillering rate, the start and finish of crop growth and maturation phases). Information on how to measure these components is in Sections 3.5.4 and 3.6.

Here are some general data collection and recording tips to consider:

- However you develop your data collection system, be consistent and attempt to track the data on a regular basis (i.e., every week on the same day).
- Collaborative planning of the data collection process with your counterpart will help you to: 1) decide on what data to collect; 2) ensure that each of you understands and buys into the purpose behind data collection; 3) ensure that someone will be responsible in case you are away from post during the trial (make sure this is communicated in advance, and that the protocol is mutually understood); and 4) increase the likelihood that your counterpart will continue data collection with future trials after you finish your service.
- Whatever system you use (e.g., spreadsheet, notebook), make sure it's something easy for both you and your counterpart to use and share.
- Make a fun ritual out of data collection with your counterpart – this can be a great time for a weekly catch-up – so make the most of it, and make it something to look forward to.

2.10 Documenting your trials through photos

SRI can be difficult to describe in words, but visual demonstrations can be powerful tools for explaining SRI principles and practices. This is all the more important in many rural West African communities due to low literacy levels and possible language barriers.

In Northern Mali, SRI technician Hamidou Guindo takes simple and clear pictures of each step of the SRI process – from field preparation to harvest – then prints (on regular paper, one image per page) for use later during small group trainings. These photos allow SRI trainees to visualize each step, *under local conditions that they can relate to*, and to see for themselves what SRI is and how it works.

Take advantage of your trial plots to develop a library of great photos to use for this kind of purpose, or for making a local training guide, a slideshow, or even a short film. Consider creating a shared folder (Dropbox, SharePoint, Google Drive, or on a computer in the capital or regional office) for all the PCVs in your country to add and share their own photos. If possible, laminate your printed photos.

Photos: Hamidou Guindo

Part 3 – Technical Step-by-Step Guide

Rice is highly adaptable, and while it can grow in flooded environments, it thrives under aerobic conditions. Above, Peace Corps Volunteers, their counterparts, and Peace Corps staff transplant young seedlings in rows with wide spacing during an SRI training in Benin. (Photo: Devon Jenkins)

Part 3 – Technical Step-by-Step Guide

Despite any planning you've already done, it's still a good idea to read through this technical step-by-step guide ahead of time, to get a more detailed idea of what to do in preparation for and during each stage of the trial.

3.1 Field preparation

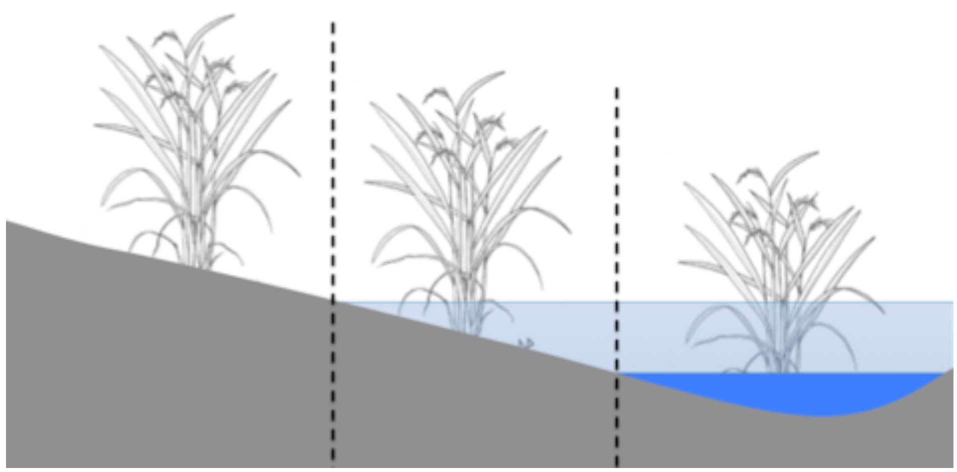
Field preparation can cover a wide range of activities, from full ***puddling*** – which literally destroys the soil structure – to Conservation Agriculture and other methods aimed at enhancing soil structure and natural biological functions. If farmers in your region are already growing rice, they likely have specific field preparation practices they're familiar with. Adapting these to SRI could mean a complete shift in how they prepare their fields, or no change at all. For many farmers, the key field preparation differences with SRI will be: 1) adding organic matter; and 2) carefully leveling/bunding the field.

In this section we'll cover some basic field preparation practices and briefly explore how these relate to SRI. In terms of soil management, our goals with SRI are pretty straightforward:

1. Strive for a soil that has a good oxygen/moisture balance – whether that means adding water, retaining water, or preventing flooding
2. Enhance the soil biotic community, particularly with additions of organic matter

How to achieve these two goals will depend largely on local knowledge and experience, what kind of rice system your farmers are using, their soil conditions, the climate, the season, and what tools and materials they have access to.

Field preparation decisions should take into account where the site sits on the ***toposequence*** – i.e., the elevation in respect to the seasonal water table, as depicted in the diagram below. Rainfed upland systems, shown on the left, have no direct access to the water table, and are not submerged. In the intermediate or transitional zones (*nappe* in French) in the middle, plant roots have access to the water table, but the fields are either never flooded, or only experience flooding for short durations after major rain events (shown in light blue). Rainfed lowland (*bas-fonds* in French, also called ***inland valley*** systems), on the right, have seasonal inundation (shown in dark blue), typically during the second half of the rainy season, and for up to 1-3 months afterward. Irrigated systems can occur at any point along the slope, depending on availability of irrigation water. *Note that this isn't to scale – these systems can exist side-by-side or many miles apart, and an individual farmer may have only one type of field, or several.*



Adapted from Perricone-Dazzo (2014).

The following chart shows a basic comparison of rice cropping zones and some field preparation issues relating to each:

Rainfed Upland (upslope fields)	Transition Zones (*nappe*) (mid-slope fields)	Rainfed Lowland (inland valleys, seasonal ponds)
Drought Prone?		
Yes	Depends	Not during the cropping season
Flood Prone?		
No	No, or only for short durations after heavy rains	Yes, seasonally
Soil Management Notes		
In areas with high and consistent rainfall, drought may not be a big issue, but for most rainfed upland areas, drought is a primary risk factor. For areas with low or inconsistent rainfall, or sandy soils, drought stress can pose serious problems. Supplemental irrigation can help, but in many cases there is no reliable form of supplemental irrigation, and soil preparation steps should be taken to increase the water retention capacity.	Transition zones can be the best place to do SRI, short of irrigated rice fields. Leveling and bunding your field can dramatically increase water control, nutrient retention, and crop establishment, and make SRI easier and more effective. Practice crop diversification and identify long-term strategies for managing soil organic matter.	Leveling and bunding your field can dramatically increase water control, nutrient retention, and crop establishment, and may provide limited ability to prevent full inundation – up to a certain point in the season.
Field Preparation Notes		
• Level and bund the field to retain rainfall, organic matter, and nutrients, to prevent surface runoff and erosion, and to promote even plant growth • Add organic matter (especially important for sandier soils) to help increase water and nutrient retention in the soil, and feed soil microbes • Use green manures, ***polycultures***, cover crops, and-/or permanent organic mulch to retain moisture, cover the soil, and increase organic matter levels • Identify potential sources of supplemental irrigation, if any such potential exists	• Level and bund the field to retain rainfall, organic matter, and nutrients, to prevent surface runoff and erosion, and to promote even plant growth • Use cover crops or crop rotation during fallow periods if rainfall is sufficient • Use green manures, polycultures, cover crops and/or permanent organic mulch to retain moisture, cover the soil, and increase organic matter levels • Identify potential sources of supplemental irrigation, if any such potential exists	• Level and bund the field to retain rainfall, organic matter, and nutrients, to prevent surface runoff and erosion, and to promote even plant growth • Use azolla (a floating, nitrogen-fixing plant) during the rainy season, and either incorporate it into the soil after harvest, compost it, or leave it on the soil and mulch above it to add nitrogen to the soil • Use green manures, polycultures, cover crops and/or permanent organic mulch to retain moisture, cover the soil, and increase organic matter levels

Farmers in each of these circumstances will almost always benefit from various field preparation techniques, such as leveling, bunding, organic matter additions, mulching, and integrated soil management strategies.

Leveling – Leveling is simply making a field *flat* (no dips or mounds) and *horizontal* (no slope), and helps prevent erosion, surface runoff, loss of nutrients and organic matter, and uneven plant growth. Larger plots or ones with moderate or steep slopes should be divided into smaller plots or terraces first, either in rectangular plots or in contour terraces. A-frame levels are simple tools that you can make at post to determine contour lines, and heavy boards (with or without people standing on them) can be pulled by people or behind an animal across a field to make it flat. Leveling the field for the first time can be a lot of work, but the payoff can make it well worth it. If farmers have large plots and are intimidated by the amount of work involved, they can consider leveling a smaller portion of their field each year, and compare the results.

Bunding – Bunding is simply construction of low, earthen, mounded walls around your plots, typically from 6 inches tall up to a couple of feet. Bunds can be used both to retain water in the field and to keep water out. For rainfed upland or mid-slope plots, bunds and leveled fields help keep rainwater in, while in irrigated or lowland rainfed plots they can be used to channel and hold irrigation/rainwater or to drain fields and minimize or prevent flooding.

Organic matter – Organic matter is an important component of SRI for all rice cropping systems and agroecological zones, and possesses many beneficial properties:

- Organic matter acts like a sponge, preventing water from percolating out of the system. Adding water-holding capacity to soils is crucial in any rainfed system, but also increases the water use efficiency in irrigated systems.
- Many organic matter particles are negatively charged, while many plant nutrients have a positive chemical charge. The ability of soils to attract and hold nutrients through their chemical charges is called the ***cation exchange capacity***, or CEC, and is an indicator of a soil's potential fertility. Organic matter can effectively increase the CEC of the soil, and as it decomposes, it releases more nutrients into the soil, acting like a slow-release fertilizer.
- Organic matter is a primary food source for soil microorganisms, promoting soil biological diversity which in turn fosters a healthy environment for rice plants.

There are many strategies for adding organic matter to the soil, and these will likely depend on what sorts of biomass are locally available. Search for locally produced material, such as waste product from local crop processing, from larger scale or semi-industrial agricultural production sources (e.g., pig or chicken farms), or from a commercial crop or processing facility (e.g., for rice, cotton, cacao, sugarcane, peanuts, palm kernels, etc). Farmers can also use crop residues, agroforestry, cover crops (if sufficient rainfall exists), and green manures. Be creative and find out what other farmers in the region have done, or check with other PCVs and your technical resources at post to see what strategies have been shown to work in your area.

The amount of organic matter to add to your field depends heavily on the type of organic matter you use and the soils you have. A general range is to use between **2 and 10 tons of organic matter per hectare** (.8-4 tons per acre).[8] While most farmers will face challenges sourcing enough organic matter, there are problems associated with using organic matter in excess or improperly:

- Too much nitrogen or potassium can cause plants to focus too much on vegetative growth at the expense of grain production, lowering yields – and can lead to a problem called ***lodging***, where plant stems grow too long and weak, causing plants to fall over.

[8] One hectare is 10,000m^2, or 100m by 100m.

- If nitrogen (through ***leaching*** or ***surface runoff***) or phosphorus (through surface runoff erosion) enter into nearby water sources they can cause ***eutrophication***, a serious environmental concern. Cumulative effects can mean that even small releases into water systems can add up to legitimate problems if they occur repeatedly or across a large area.
- Manure and other organic matter sources that are not properly decomposed (composted) before using in the field can burn plants.
- Improperly decomposed compost and poorly chosen mulches can contain weed seeds.

Organic matter can be applied evenly across a field in concentrated doses, to achieve more of a critical mass effect, or at differing rates to enable comparisons between application rates. In more arid zones, or where organic matter may be difficult to come by, concentrating it into planting holes can be an effective strategy (similar to the zaï system from Burkina Faso, or how Conservation Agriculture is practiced in parts of Southern Africa), or organic matter can be incorporated directly into the soil within the planting rows using a ripper. Farmers can also focus their organic matter applications on a specific part of their field for one or more seasons, and then move on to another section once this part reaches an adequate level, then repeat in a rotation.

Mulching – ***Mulching*** is another good option for maintaining soil moisture and protecting soil structure from damage caused by hard rainfall, erosion, or wind. In tropical climates, creating or maintaining a mulch cover can be challenging. In many locations where animals are grazed in the dry season, crop residues or mulch can end up being eaten by animals or termites. Mulch can be generated on- or off-site from crop residues, alley cropping, green manures, cover crops, agroforestry, and other similar sources.

Integrated soil management strategies – Strategies like ***Conservation Agriculture*** (CA), which aim to preserve and enhance the soil structure and biotic life, are completely compatible with SRI but are only beginning to be used in tandem with it. SRI was developed with irrigated rice in Madagascar, and irrigated rice traditionally involves completely puddling the soil to create a hard pan below the surface and trap water in. This practice destroys the soil structure, and along with flooding, damages the soil health. SRI commonly promotes using active soil aeration, typically using a rotary weeder to kill weeds, break up the soil, and aerate it at the same time. While helpful for the rice plants (it stimulates root growth, and increases microbial activity and nutrient mineralization), it can damage the soil and use up organic matter more quickly. As a result, attention has recently started shifting toward combining SRI with practices like CA.

Conservation Agriculture uses three principles: constant organic soil cover (with cover crops, relay crops, crop residue, or mulch); crop diversification (either in time using crop rotations or in space using crop associations); and zero (or minimal) tillage to leave the soil intact. CA started with large-scale industrial agriculture in Brazil in the 1970s and 80s, and has become popular both with industrial farmers in North America and Europe, and smallholder farmers across Southern, East, and Central Africa. While the methods are radically different between industrial scale and smallholder scale applications, the principles are the same.

3.2 Crop establishment options

There are two primary methods for crop establishment – ***indirect seeding*** (transplanting) or ***direct seeding***. Choosing which method to use will depend largely on what type of rice system is used in your area.

Indirect seeding, as the name implies, means starting your seeds in a location other than your field – a nursery – and then transplanting them into the field. Direct seeding is simply sowing your seeds directly into your field.

Transplanting is often preferred for SRI because it offers two distinct advantages, both of which will be familiar to anyone with vegetable gardening experience. First, transplanting allows you to choose only the healthiest plants, so that you can avoid having empty or underperforming spots in your field. Because so much less seed is used with SRI, each plant is responsible for a much greater share of the yield, placing even greater importance on ensuring the health and vigor of each plant. Second, transplanting gives the rice seedlings a head start over weed competition, increasing their vigor and reducing the labor needed for weeding.

Despite these advantages, there are very good reasons for farmers to use direct seeding instead of transplanting. The two principle reasons are rainfall patterns and labor issues.

In rainfed upland conditions, farmers have to time their planting to coincide with the start of the rainy season. Since rainfall early in the season can be sporadic and unreliable, it can be difficult for farmers to gauge when to plant. If they plant too early their crop could get stunted or die, and they'll be forced to plant again, perhaps several times before their plants take. If farmers plant too late – particularly in places with short growing seasons – they run the risk of the season ending before their crop has reached maturation, or preventing a second crop in places with longer growing seasons. SRI may mitigate this difficulty to some extent, as it typically causes plants to ripen 1-2 weeks earlier than normal.

Under traditional practices, farmers have more leeway to keep their rice seedlings in the nursery until the rains arrive, and seedlings often stay in the nursery for 3-5 weeks or more. Under SRI, however, farmers don't have this leeway and should transplant when the plants have two leaves. With direct seeding this isn't an issue, and if for some reason their seeds fail to take, the process is far simpler than setting up a nursery so repeating it isn't as labor intensive or frustrating.

In places where labor costs are high, or where there are competing demands for labor for other crops, direct seeding may be the most cost-effective option.

Instructions for setting up a nursery and transplanting are presented in Section 3.3; instructions for direct seeding with SRI are in Section 3.4.

3.3 Indirect seeding (nurseries and transplanting)

Whether or not farmers in your area already use nurseries and transplant, the processes of both setting up a nursery and transplanting are often new to farmers. SRI emphasizes treating each individual plant with great care, and giving young seedlings the best possible conditions to get established. Because of this, how you set up and manage your nursery is important.

3.3.1 Deciding on spacing for indirect seeding

If you have no prior experience with SRI, or are unsure about how a specific variety will perform, the general rule of thumb with SRI is to start with a **25 cm x 25 cm spacing**. With experience, consider adapting this to the local conditions by observing your field throughout the vegetative growth phase to see how quickly the plants fill in the space in between rows. If the space fills quickly and there is plenty of extra time left before the reproductive phase starts, then the spacing can likely be increased next year and the plants will be able to take advantage of the extra space. More rarely, if the space between rows fills slowly, or even not completely, then consider using a slightly reduced spacing the next year – or adding more organic matter to your soil, and looking for varieties that might tiller better. Spacing can generally increase up to 40cm by 40cm, and decrease as low as 20cm by 20cm, though this tighter spacing should be avoided if possible.

3.3.2 Setting up a nursery

Because the timing of when you transplant is extremely important with SRI, be sure to think through exactly when you will want to start your nursery. All necessary preparations (e.g., field preparation, sourcing or making marking tools, labor for transplanting) need to be ready and in place by the time the seedlings reach the two-leaf stage, which is typically 8-12 days after germination. The best advice is to play it safe for the first trial, and have all these steps done before you start your nursery.

The nursery should be 1% the size of the field you'll be transplanting into, and in **1-meter wide strips**, which prevents people from stepping on the nursery bed to weed or water the seedlings. For a demonstration field that's 10m x 10m ($100m^2$), the nursery bed would be $1m^2$; for a demonstration field that's 10m x 20m ($200m^2$), the nursery bed would be $2m^2$, in a 1m x 2m strip. When you scale up to larger fields, keep the same ratio, again using 1m-wide strips:

- A .25 hectare field ($2{,}500m^2$) would have a $25m^2$ nursery bed, which would be 1m wide by 25m long; you would likely break this into several shorter nursery beds, each 1m wide.
- A 1 hectare field ($10{,}000m^2$) would have a $100m^2$ nursery bed, which would be 1m wide by 100m long; you would absolutely want to break this into many shorter nursery beds, each 1m wide, but totaling $100m^2$ (e.g., 5 separate beds, each 1m x 20m)

Site your nursery somewhere that's easily accessible, with reliable access to water, and where bird, ant, or rodent problems aren't likely. Ideally it should be very close to the field – since you'll need to transplant the seedlings within 30 minutes of uprooting them – but still somewhere that can be easily monitored on a daily basis. If the field is far away from where you or your counterpart live, consider planting the nursery in containers that can be easily transported to the field for transplanting, in order to avoid uprooting them and leaving them exposed to the sun and dry air for more than 15-30 minutes when transplanting. When doing this just make sure to have deep enough soil and free drainage to prevent waterlogging, and use care when transporting.

Make the beds into straight rectangles, using twine and stakes to mark them out. The beds should be raised to allow for good water drainage and easier uprooting of the seedlings. Follow these steps to create the nursery beds:

1. *(optional)* Line the soil with banana leaves, if available, to prevent weed growth and make uprooting easier, and perforate the banana leaves to keep water from accumulating and suffocating the seedling roots.
2. Build up a rich yet free-draining soil medium by mixing equal parts soil, compost/aged dry manure, and sand (as possible). Aim for a texture that will allow you to easily separate seedling roots when transplanting, but won't be so loose that the soil will fall right off the roots.
3. Break up soil clumps to create a smooth, consistent texture.
4. Build the soil mixture up to a height of 10-15cm above ground level (on top of the banana leaves, if you used any) – deep enough to accommodate root growth and prevent the roots from entangling.
5. Rake the surface to get a smooth, flat, and level seed bed – pockets, mounds, or a slope will create channeling and erosion, and result in inconsistent seedling growth.
6. Start watering the seed bed a few days before sowing to pre-germinate any seeds, and settle the soil a bit, removing large air pockets; use a watering can if possible to avoid erosion.

3.3.3 Calculating seed requirements

Farmers are often skeptical about the amount of seed needed for an SRI trial, so expect a bit of resistance at first, though through experience they'll begin to feel comfortable seeding such small amounts. For SRI using indirect seeding (transplanting), a good rule of thumb is to use 8.5 kg/ha, which works out to **85g of seed for each 1m² of nursery area, if using certified seeds**. If using noncertified seeds, and you plan on sorting the seeds to remove nonviable ones, add an extra buffer of 15-20% to account for the seeds you'll be removing – meaning a rate of **100g of seed per 1m² of nursery area for noncertified seeds**.

3.3.4 Seed sorting, soaking, and germination

Since SRI uses 80-95% less seed than traditional methods, it's important to make sure that you're using the best seeds possible, regardless of the variety you've chosen. Seed selection has two parts:

1. Selecting the best seeds at the time of harvest
2. Sorting the seeds at the time of germination

The first step, which requires advance planning, may not apply to your first season of trials, but you can prepare farmers to do this in the future. The idea is simple: walking through the field before actually harvesting the plants, the farmers select the fullest, largest panicles, with the healthiest and largest grain, and set these aside to use the following year.

The second step, seed sorting, doesn't require advance planning. An easy method of sorting seeds is to submerge them in a bucket or bowl of water – the denser seeds will sink to the bottom, while the less dense seeds will float to the surface. Less dense seeds are less fully developed or filled, and will result in less vigorous seedlings, so it makes perfect sense to remove them. When sorting seeds you'll need to measure out enough seed to account for the seeds that you will discard. Add a 15-20% buffer, resulting in a rate of approximately 100g of seed per 1m² of nursery bed, or 10kg per hectare.

For even greater accuracy, you can use the same sorting method, but with a salt-water solution instead of plain water. Adding salt to the water changes the buoyancy of the seeds, further separating even partially filled grains. There is a simple method for determining how much salt to use: add salt to the water until it causes a raw egg to float to the surface – the egg acts simply as an indicator of an appropriate concentration of salt to use.

1. Measure out and add the required amount of seeds and place in a bucket.
2. Cover with 10-20cm of water.
3. Add one raw egg.
4. Gradually stir in and dissolve salt until the egg floats to the surface (it takes quite a bit of salt!).
5. Remove the egg, stir vigorously, allow things to settle, then discard any seeds that are floating.
6. Thoroughly rinse seeds until they are no longer salty (approximately 3-4 rinses).

After separating, soak the seeds in clean water for 24 hours, in a shaded or dark location. Next, remove them from the water and spread them out on an empty sack in a thin layer, cover with a second sack, and leave in a dark, sheltered place for another 24 hours to begin germination. While germinating, keep them protected from rats, birds, etc. After about 24 hours a white spot should appear on the grain – an early sign of a developing root, and an indication that the seeds are ready to be sown. For colder climates (or during colder times of year), germination is more prone to being spotty or inconsistent, and seeds should be germinated in a warm location. If seeds have developed roots or small shoots, be extra careful not to damage them when handling and sowing.

3.3.5 Nursery management

Once the germination has started, sow the seeds in the nursery, giving them a little extra space between each seed to prevent the roots from getting entangled. An easy method of ensuring a good, consistent seeding density is to sow the nursery bed in stages:

1. Divide the nursery bed into two equal parts.

2. Divide the germinated seeds into three roughly equal parts.
3. Evenly broadcast the first portion of seeds across the first half of the nursery.
4. Evenly broadcast the second portion of seeds across the second half of the nursery.
5. Use the remaining portion of seeds to fill in any gaps, trying to keep seeds from overlapping as much as possible.

Evenly cover the seeds with a 1-2 cm layer of fine soil or sand, which will help keep them in place when watering and protect them from drying out. Next, cover the beds with a layer of palm fronds or straw (avoid using rice straw if it could contaminate the nursery with seed from different varieties) to protect from birds, rodents, and heavy rains – or, if available, cover with a layer of shade cloth.

Water the nursery 1-2 times per day – enough to keep it consistently moist but not waterlogged. Check it multiple times per day if possible, to prevent insect/rodent/bird damage (birds can be a problem early in the morning, especially the first few days), or drying out. When the shoots start to emerge from the soil, gradually raise or remove the palm fronds, straw, or shade cloth. Keep an eye on the beds, and when more than half of the seedlings reach the two-leaf stage, it's time to transplant. This stage doesn't last for long, so be ready to mobilize your transplanting team by letting them know a couple of days in advance that you anticipate transplanting.

You can influence to some degree the timing of your nursery by how you water or provide shade for the seedlings. If, for whatever reason, you need to slow down their growth to delay transplanting, water the nursery a bit less and keep the shade cloth or palm frond covering on a bit longer. If you need to speed up the seedling development, water the nursery more frequently and remove the shade cover earlier.

3.3.6 Marking and transplanting strategies

There are many strategies for marking and transplanting; here, we'll review three common ones:

1. Marking rakes
2. Marking rollers
3. Transplanting ropes

Familiarize yourself with the options, and once you and your counterparts have decided on an approach that would be best for your circumstances, prepare all the necessary materials. It's a good idea to do a simple trial run before having a team come help with the actual transplanting – even if farmers in your area are familiar with transplanting, the process is a bit different under SRI. Section 3.3.7 provides additional tips for transplanting.

1. Marking Rakes

   Marking rakes are simply rakes with tines that are evenly spaced to the width you'll use for your transplanting. In most cases, this spacing will be 25cm between the center of each tine, and for a first trial this is a great spacing to start with. Rakes can be made of any material, including rebar, scrap metal, bamboo, lumber, branches, or a combination of these. Each material has advantages and disadvantages. Metal is durable and the extra weight can be helpful in keeping the rake from lifting out of the soil as it is dragged along the field, but can be more costly and difficult to build (though typically easily made by a local blacksmith). Wood or bamboo rakes can be cheap and quick to make, but can lift out of the soil a bit, create excessive drag, make less clear lines, and be less durable. Also, consider using a less expensive design for a first trial, since the ideal spacing for local conditions may end up being different from what you start with.

   The type of soil you have – and how you prepare it – will affect the performance of the rake you use. Heavier, non-sandy soils can hold on to marks better, but if the soil's not well prepared (leveled and drained) the marks may not show. Sandier soils will require thicker and deeper tines, and perhaps a heavier rake. The user's gender, age, and strength may also be considerations: a heavy rake could be a barrier to use, or cause discomfort or pain.

Marking rakes have some distinct advantages over transplanting with a marked rope: 1) they allow the marking itself to be done quickly, by a single person, instead of by a team; and 2) the marking can be done ahead of and separate from the team that actually does the transplanting. (With a rope, the markers and the transplanters work in tandem, meaning that a delay with one team can slow down the whole process.) However, if the soil isn't properly prepared, the marks may not show, and a marked rope may be much more practical.

How to use a marking rake:

a. Use a length of twine to set up a straight line along one edge of the field, and use this as your guide, then mark the entire field with one set of parallel lines.
b. Create the crossing set of parallel lines, checking to make sure your new guide line is perpendicular (90°) to the original guide line; if you're not sure, you can set up a right angle by making a 3-4-5 triangle from a 12m length of rope – the 90° angle will be between the 3m and 4m lengths.
c. Walking forward across the field, the transplanting team can start at any time once part of the square grid is ready, placing one seedling at each intersection where the lines meet.

Photo: Devon Jenkins

2. Marking Rollers

Rollers are an adaptation of marking rakes. Instead of marking one set of lines then going back over the field to mark a perpendicular set of lines, rollers create a square grid in one pass.

Rollers are simply barrel-shaped devices that can be dragged or pushed across the field, leaving a grid impression the width of the roller. While they save time, they can be a bit trickier to make, since they involve a rotating part and the grid spacing needs to be carefully measured out. Rollers are often made out of rebar or bamboo, and some use bicycle wheels as a frame – but check the circumference to make sure it is consistent with the spacing you will use.

One challenge with rollers is making sure the mark shows up well, which can require some additional weight. Rollers also aren't suitable for some soils, especially if the field isn't very level/flat, or when there are small mounds, valleys, or standing water; they work best in fine mud.

How to use a marking roller:

a. The process is exactly the same as with a marking rake, except that you only need to do one pass through the field – though be careful to align the rows properly.

Photos: Devon Jenkins

3. Transplanting Ropes

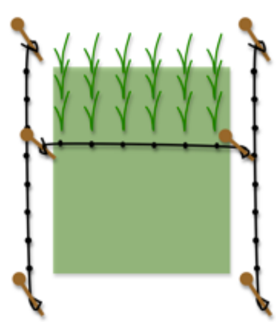
Transplanting with a rope is a versatile approach that, while a little tricky at first, can be used quickly and efficiently with some practice. Transplanting ropes can be used for any soil, regardless of how level or flat the field is. Unlike rakes and rollers, however, no grid is laid down in advance, meaning that the rope and transplanters need to move together for each row that they transplant. This can be a limitation, and can slow down the transplanting process. In addition to this, rakes and rollers can be easily used with just one person, whereas a transplanting rope usually requires at least two to three people, often more. As with rollers, the spacing is fixed, and a separate rope will need to be prepared for each spacing width you decide on.

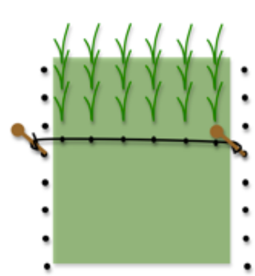
To prepare a transplanting rope:

a. Measure a length of rope long enough to cover the width of your plot.
b. Mark the rope by tying strips of fabric or plastic every 25 cm ***into*** the rope itself, not around it (to prevent them from slipping).

Transplanting can be done using three separate marked ropes, or just one. Three ropes take extra time to prepare, but make transplanting faster. For a three-rope system, two of the ropes are staked along opposite sides of the plot to act as guides, and a third rope is moved in between them to mark where the plants should go. When using only one rope, the rope is first used to mark holes along both sides of the plot, then staked between the holes and moved for each row that is transplanted. In both cases make sure the two sides are aligned.

Using three ropes





Using only one rope

To use a transplanting rope:

a. Mark the sides of the plot using the two extra ropes, or marking holes if using one rope.
b. Using your guide ropes or guide holes, line up the transplanting rope with the first set of guides, stake it down taught, and transplant the first set of seedlings along the rope at each marking knot or fabric strip – make sure to plant along the same side of the rope every time, to avoid plants being staggered and not uniform.
c. Move the rope forward to the next set of markers, and repeat.

Photos: Erika Styger

Transplanting with a marked rope can be quick, versatile, and accurate, and works with all soil conditions. Note that the fabric is drawn through the rope rather than tied around it. This keeps the markers fixed in the same place in the rope.

4. Other marking systems

   An interesting adaptation of rollers is a triangular frame roller made out of three straight poles set 25cm apart, with connecting cross pieces placed every 25cm. The roller is laid down on the field, and seedlings are transplanted at each cross bar. When one row is done, the triangular frame is simply rolled forward, and another row is transplanted. This type of marker can be used by a single person, and with any soil conditions. Similarly, some farmers have adapted flat grid markers – like an elongated tic-tac-toe board. Instead of being rolled, these are simply laid flat on the ground, then picked up and advanced once each transplanting set is finished.

3.3.7 Good transplanting practices

One of the four principles of SRI is early and healthy plant establishment. This principle helps make sure that each small seedling can start growing rapidly, develop robust root systems, and have the longest possible period for tillering. During transplanting there are a few key things you can do to make sure the seedlings can quickly recover from transplanting shock and start growing:

1. **Keep soil intact on the roots.** Keep the soil intact around the roots from nursery to field.
2. **Handle the seedlings with care.**
3. **Use only the healthiest seedlings**. With fewer plants you can and should be picky!
4. **Get each seedling in the ground within 15-30 minutes from leaving the nursery**. Leaving seedlings out longer than 30 minutes can dramatically increase the shock they experience; only take out as many seedlings at a time as can be transplanted quickly in 30 minutes or less.

5. **Keep the roots from becoming inverted.** Often farmers will push seedlings straight down into the soil, causing the ends of the roots to push back upward toward the surface, in a "J" shape, which takes several days for the plants to correct. To avoid this, simply make a small hole or trench with your finger, and drag the seedling into the soil, then pat down gently on top of the soil to remove air spaces, which will result in more of an "L" shape, and take less time for the seedlings' roots to start growing downward.
6. **Don't transplant too deeply.** Rice seedlings don't need to be planted deeply, and if they are, it will limit the amount of tillering they can do. One to 2cm will suffice.
7. **Transplant only one seedling per space.** Work side-by-side with your counterparts, and make sure everyone is planting just one seedling per space.

3.3.8 Crop establishment after transplanting

If possible, water the plants in well immediately after transplanting, but be careful not to flood or wash away the seedlings. The plants will experience some shock after transplanting, so it's normal for them to turn a bit yellow. Treat them with a bit of extra care for the first 10-14 days after transplanting. Water them as needed, perhaps daily if the weather is hot or dry, and hand weed if needed.

Starting 10-14 days after transplanting, you can begin the SRI field management outlined in Section 3.5.

3.4 Direct seeding

3.4.1 Seed selection, sorting, and germination

Seed selection, sorting, and germination are important components of SRI – particularly for direct-seeded SRI. Follow the steps in Section 3.3.4, above, for a simple yet effective means of selecting the most viable seeds.

3.4.2 Spacing, plant depth, and seed quantity

As with transplanted rice under SRI, 25cm x 25cm is a good spacing to start with for initial trials. If the soil is very fertile, with plenty of organic matter, and if you are using a variety of rice that is known to tiller well (which is often the case for longer-season varieties – see Section 2.6), then you can increase the spacing. Again, there's no fixed recipe for SRI – feel free to experiment, but keep things simple and straightforward for an initial trial, since the primary point is to prove that it works.

For soils which are less fertile and lacking in organic matter, or if you are using a variety that is known to be upright in shape and not tiller well (some shorter season upland varieties – see Section 2.6), consider decreasing the spacing slightly to 20cm by 20cm. In any case, always keep the spacing the same in both directions, and if in doubt, start with a spacing of 25cm.

Seeds should be sown superficially, that is, cover them with just enough soil to prevent them from washing away or being eaten by birds, insects, or rodents. Seeds that are planted too deeply won't tiller as well.

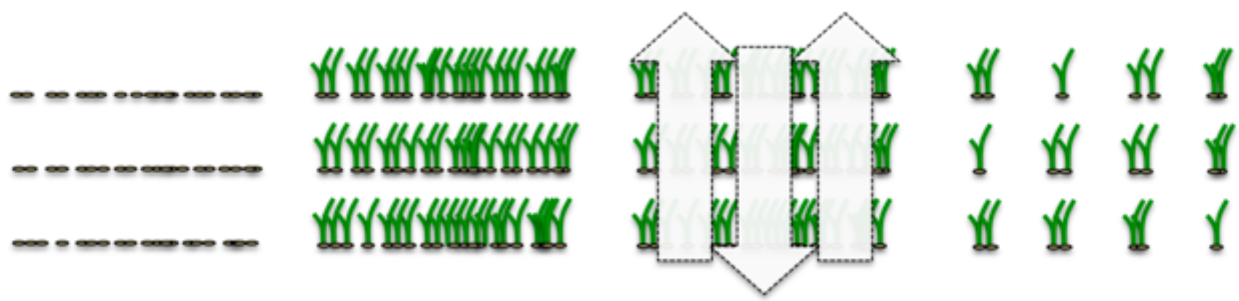
When using direct seeding, it's a good idea to sow 2 seeds per hill (space). Inevitably, some seeds won't germinate or will be stunted; having two per hill allows you to fill some of the empty spots with healthy seedlings from other spots in the field. To do this, wait until the seedlings are at the two-leaf stage, and transplant the extra seedling from hills with two healthy seedlings to those without a healthy seedling. Once you've filled in any gaps, you can choose to either thin the remaining double seedlings, or simply leave them in place. Keep track of what practices you do, and what the labor expenditures are (time and/or money) to calculate the most cost-effective practice.

When sowing two seeds per hill, the seeding rate is approximately 17kg/ha if using certified seed, or 20 kg/ha if using noncertified seed (to account for seed discarded after sorting).

3.4.3 Sowing methods

How you sow your field will depend on what resources are available. Whatever method you use, aim to be as consistent as possible with your planting grid to ensure easier weeding and more uniform plant development. A marking rake can be used to trace out the grid in wet soil (after a rain), and then the farmers can plant two seeds at the intersections of the lines. Farmers can also use a transplanting rope to mark out holes with a stick for seeding. See Section 3.3.6 for marking ideas and strategies.

In Senegal, where inexpensive animal-drawn machines are common, farmers have adapted a direct seeding method for SRI to save labor costs. First, using the sowing attachment for the machine, they sow in line, using wide spacing between rows (at far left in the diagram below). Then, using a weeding attachment for their machine (of an appropriate width for SRI line spacing), they return when the seedlings are at the two-leaf stage (second from left) and move across the field perpendicular to the original line seeding (second from right), removing all but the seedlings at the grid intersections (far right). Any extra seedlings (beyond 1 per hill) can be thinned by hand and used to replace empty hills, or simply left in place. Alternatively, farmers can reduce in-row spacing between plants by choosing a seeding disk with wide spacing and/or mixing in sand with the seed, potentially negating the need to thin between plants.



This simple approach uses more seed, but reduces labor requirements, and was both preferred by farmers in the area and found to be more economical (Perricone-Dazzo 2014).

A variation on this would be to use a drum seeder to sow in lines with SRI spacing, then weed in a perpendicular direction with a ***cono-weeder,*** hoe, or other common SRI-type weeder to thin the plants. As with the first example, the remaining plants could be hand-thinned to 1 per hill or left as is.

This example illustrates one way that SRI can be economically adapted to local circumstances. Use this as inspiration to search for other innovations that can achieve SRI benefits in a cost-effective manner.

3.4.4 Plant establishment

After sowing, hand-weed the field for the first 3 weeks, and use supplemental irrigation (if available) to keep the plants from becoming drought stressed. Unless used for thinning (as above), wait to use mechanical weeders until the plants are well established. Around 3 weeks or so after seeding, begin mechanical or hoe weeding and intermittent watering (where possible), as outlined below in Section 3.5.

3.5 Field management after plant establishment

Once the plants are established in the field (7-10 days after transplanting, or 3 weeks after germination if direct seeding), it's time to start SRI field management. This management lasts for the rest of the vegetative growth phase. Once flowering starts, SRI management ends, and farmers can follow whatever practices they would normally use.

This section covers SRI field management during the vegetative growth phase:

Plant Establishment	Vegetative Growth Stage	Flowering, Grain Filling, and Maturation Stages
Keep soil moist and hand weed	Follow SRI management practices; keep soil aerobic	Stop using SRI management practices; keep soil moist if possible until 2 weeks before harvest
Take extra care	SRI crop management	Normal crop management

3.5.1 Water management

There is no prescribed SRI water management calendar because each field and circumstance is different. Weather, climate, rice variety, soil texture, soil structure, organic matter additions, etc., all impact the watering cycle, so you will need to develop your own sense of when and how much to water based on observations and your understanding of the SRI principles. Fortunately, rice plants are tolerant, and SRI water management is fairly intuitive. Remember, an initial trial should be primarily about introducing and verifying the SRI concept to farmers; after this, future trials can be more concerned with testing optimal variations under local conditions, including differences in water management.

One important variable is the degree of water control available to farmers. Some farmers have excellent control over water year round, others have excellent control at certain times of the year, and some have no control at all. Despite this, all farmers are capable of soil and field management practices that can help retain or withhold water to varying extents. For more on this, see Section 3.1.

The goal is to achieve a soil environment that is moist but aerobic, and is a healthy habitat for soil biotic life. You want to avoid letting your plants and soils become deprived of oxygen, but also avoid drought stress. When watering, add enough water to briefly saturate the soil, but do not keep it saturated for long. As with many houseplants, a generous amount of water every week or 10 days is often a good starting point. Depending on the sand or clay content of the soil, you may need to water more or less frequently and with greater or lesser intensity. If plants show any signs of wilting or drought stress, water them immediately, and adjust your watering schedule accordingly. In hot, dry, and/or windy weather, keep a close eye on your plants, and be prepared to water at any time.

If you are using a mulching and/or zero-till strategy, you may need to water less frequently, and should carefully monitor the soil to make sure it is able to dry out a bit between each watering.

3.5.2 Weed management

Weed management under SRI can be either active or passive.

With active weed management, farmers use a hoe or specialized mechanical weeder to kill weeds and mix them back into the soil, adding more organic matter in the process and aerating the soil at the same time. Weedings should be done early (after the plants are established) and frequently, to keep weed pressure from limiting the growth potential of the rice plants. Frequent, early weedings promote more vigorous rice plant growth, which decreases the time it takes for the space between rice plants to close up – at which point weed pressure will no longer be a serious issue. If farmers wait too long before the first weeding or in between weedings, the rice plants might not fully fill all the extra space they're given under SRI, which can lower yields and give farmers negative impressions of SRI.

Local conditions vary widely, so there is no universal SRI weeding schedule. As a rule of thumb, weed every 7-10 days, up until there is no longer need or enough space left between rows to permit weeding.

Weeding by hand is difficult, time consuming, and potentially expensive (if the farmers hire labor). However, the farther behind a farmer falls, the harder weeding becomes and the more negatively the weed pressure impacts the rice plants. This is a good reason to start small with a first trial – a small plot is easy to weed, and therefore easier to demonstrate how SRI works. With some practice and experience, farmers can adapt tools or methods for making weeding faster, easier, and cheaper.

There are many types of mechanical weeders available, each with advantages for different types of soil or cropping systems. Weeders for sandier or drier soils often have a small chisel plow or even a blade that cuts just under the surface. Rotary weeders, like the popular cono-weeder, are more common for heavier lowland soils. Ask around in your area and see what (if any) weeders are available for the soil types you work with. For more information on different weeder types, including diagrams for getting weeders locally produced, see the Resources section in Appendix A.

As the rice plants grow, they will fill in the space between the rows and weeding is no longer practical. Typically farmers can do three to four weedings before this happens, and field experiments have shown that yields increase with the number of weedings done. Each weeding takes time and/or money, so farmers should do a cost/benefit analysis with each trial to see if additional weedings increase yields enough to cover the added costs.

For irrigated rice fields, time your weedings at the end of each watering cycle to allow maximum aeration for the rice and minimize any watering benefit for the weeds. In heavier soils with higher clay content, especially when using a rotary weeder, keep 1-2cm of water on the field while weeding to keep soil or mud from clogging the weeder.

The downside of mechanical weeding (aside from the labor involved) is the disturbance it causes to the soil and the soil biotic community. Mechanical weeding can increase the rate of nutrient use in the soil, disrupt earthworms and other soil organisms, and damage soil structure. Farmers can instead test out passive weed management strategies.

With passive weed management, a layer of crop residue, mulch, and/or cover crops is used to suppress weed growth, retain moisture, add nutrients and carbon to the soil, and enhance soil biotic life. Since SRI was developed with mechanical weeding, this is a relatively new approach to SRI, and good management practices are still being developed. ***Conservation Agriculture***, or CA, is one methodology that's becoming popular throughout parts of Africa, primarily for non-rice crops, and can be used in conjunction with SRI. Some resources for CA are found in Appendix A (under "Soil and Fertility Management, Conservation Tillage/Agriculture").

Passive weed management with mulching/crop residues can be difficult in areas where little organic matter is available (e.g., in more arid areas), where competition for organic matter is high (whether for livestock, fuel use, or because of predation by termites), or where fields aren't very secure (i.e., neighbors or untethered animals could take/eat the mulch).

Despite these challenges, creative solutions can often be found. If there is a local industry with a waste by-product, such as sugarcane or rice milling, see if this can be sourced for free. Be careful to avoid using mulch that contains seeds, especially from weeds or other rice varieties. As with all transitions, the first few years could be challenging, so consider phasing in different parts of a field each year.

3.5.3 Soil fertility management

In addition to organic matter, which was already discussed in Section 3.1, farmers can of course use synthetic fertilizers on their rice fields. Traditional rice varieties are often well adapted to not needing synthetic fertilizers, but many high-yielding varieties were bred specifically to be used with synthetic fertilizers and may not perform well without them.

Nitrogen (N) fertilizers promote vegetative growth, but excessive nitrogen can lead to excessively tall plants, which can lead to the plant growing too tall and falling over (a condition called ***lodging)***, which will reduce yields. Furthermore, excessive nitrogen and phosphorous (P) fertilizers can also cause significant environmental damage to aquatic life in the form of ***eutrophication***. Both synthetic and organic sources of nitrogen can lead to eutrophication, so be careful to ensure that these are well incorporated into the soil when applying them, and that runoff doesn't wash into streams or lakes, especially for manure that hasn't been composted or decomposed yet. One method to reduce potential environmental damages is to apply urea in conjunction with weeding, as your irrigation water is subsiding (for irrigated rice). Better yet, in places where a urea deep placement (UDP) program is operating, consider testing this method. Many NGOs around West Africa promote UDP programs, and the Peace Corps staff in your country can likely help you identify one.

You can follow local guidelines or consult an extension agent for fertilizer dosage and timing, matching recommendations for your soil conditions and the variety you are using, but keep in mind that these were almost certainly not developed in the context of rice farming systems that rely heavily on organic matter. As much as possible, attempt to use synthetic fertilizers only on a supplemental basis, realizing of course that depleted soils may need some added fertilizers.

3.5.4 Data collection during the trial

Data about the crop's yields is most often used to compare the results of a trial, but by itself, the yields data doesn't really paint a full picture about *why* certain results were achieved. Collecting measurements throughout the trial can help identify what variables contributed to the yields. Consider planning regular visits to the field throughout the season to collect measurements, perhaps on a weekly basis, and on the same day.

While there are many possible strategies to use, pick a simple one and be consistent. Make sure that your strategy is representative and random, and to not collect data from plants directly on the edge of the plot (due to the edge effect, where these plants will tend to grow better because of reduced competition and more sunlight – a bit like SRI). One simple strategy is to walk the two diagonals of the plot (between opposite corners), randomly picking ten plants or so just after transplanting or during the first few weeks after direct seeding. These same plants would then be used for each sample, so mark them in some indicative manner that will be easy to keep track of during the entire season (with a numbered bamboo stake, for instance). Lastly, remember to plan this step with your counterparts, making sure they understand the purpose in doing it and can do it if you are away from post. Be consistent about when and how you collect, always collecting data from both the SRI plots and conventional plots at the same time.

Some possible variables to track include:

- Plant height – spread the plant out as high as you can, running the longest point (whatever that part happens to be) between your fingers, then measure from the ground to the tip.
- Number of tillers per plant – each tiller is a separate stem, but the "flagging leaves" that fall off to the side of the tillers don't count as tillers themselves.
- Number of tillers per hill – for SRI there will normally be 1 plant per hill, but for the conventional plot there will typically be many more plants per hill—so count the tillers from all of the plants if measuring by hill.
- Number of panicles per plant.

Recording important dates is a good practice that can help identify factors that can affect yield and general crop performance. If you keep a specific notebook for your trial as a log, record as much of the following information as you can throughout the trial, noting dates for each event for both SRI and conventional plots:

- Germination/sowing
- Transplanting
- When panicles first emerge
- When half the plants have panicles
- Harvest
- The beginning and end of any periods of natural flooding/inundation
- Watering frequency
- Weather events

3.6 Harvesting[9]

Careful harvest planning is important to ensure an accurate measurement of your yield. Make sure to involve your counterpart in all the planning steps, and invite local farmers to participate.

Be consistent in how you execute each step of the harvest process, ensuring that the SRI and control plots are measured in exactly the same way. Use the same procedures and tools, and be present yourself to verify that everything matches up.

One area where consistency may not be entirely practical is the harvest date. While the SRI and conventional plots should have been started on the same day, SRI management often causes plants to mature 1-2 weeks earlier than normal. If this ends up being the case, simply harvest the respective plots when they are ready, but use the same methods for both, and note any relevant changes that may have occurred in the interval between the two harvests, such as pest attacks.

If your plots are small enough, the entire plots can be harvested to calculate the yields. This is covered in Section 3.6.1. If the plots are larger – and if you have access to a precision scale – it may be easier to use a representative sample of the harvest for your calculations. This is covered in Section 3.6.2. If you absolutely can't be around during the harvest, and are unsure about whether your counterparts will be able to effectively do one of these two harvest methods, they can instead follow a simplified approach, detailed in Section 3.6.3.

Note: All calculations and conversions are presented in Appendix H.

3.6.1 Harvesting from the entire plot (for smaller plots)

Materials:

- Measuring tape (can often be borrowed from a local school)
- Yard stick
- A shovel or hoe
- Scythe or machete
- Scale from the village that can measure rice sacks in kg
- Rice sacks
- Threshing / winnowing materials – the same as what farmers normally use (e.g., mats, sticks)

[9] Material in this section was developed by Erika Styger, SRI-Rice.

Step-by-step:

1. Observe the field, walking around the plots and discussing / taking notes about visible characteristics. Did the plants develop uniformly? If not, describe the differences in terms of color, height, timing of maturation, grain fill, etc.
2. Mark a 1-meter strip along the entire edge of the plot. Edges often develop differently from the rest of the plot and can skew yield calculations. Harvest this strip and set it aside to be threshed and winnowed separately, making sure it won't get mixed in with the rest of the rice that will soon be harvested. If the plot is very small or narrow (3-5m), simply remove one or two rows of plants instead.
3. Select 10 plants from the plot to measure before harvesting them. If you've been tracking a randomly selected but specific set of plants through the season, simply use these. If not, walk the two diagonals of the plot (between opposite corners), and randomly choose five plants on each diagonal, being careful to not favor plants based on health or size.
4. Measure the height of all 10 plants (in cm) from the ground to the tip of the tallest leaf or panicle, stretching the plant out by sliding it upward between your hands.
5. Harvest all 10 plants (from the base) and set them together on a mat or slab, then measure the following variables and record them in your trial log:
    - Number of tillers per plant or hill (if there are multiple plants per hill)
    - Number of panicles per plant or hill (if there are multiple plants per hill)
    - Measure the length (in mm) of five randomly selected panicles (total, from all 10 plants), starting from the node/notch at the base of the panicle to the longest point
    - Count the average number of grains from these five panicles
6. Harvest the rest of the plants and set them with the 10 sample plants, again keeping these separate from the previously removed border strip. The grain may need 1-3 days to dry (out of the sun) before weighing it – follow the farmers' advice, and follow the same practice for the SRI and non-SRI plots.
7. When the grain is dry, thresh and winnow it, and weigh it as soon as possible, using a field scale if available, and record the weight in your trial log. If no field scale is available, find out what farmers in the area typically use to measure their harvest (e.g., a large rice sack, calabash, or metal bowl), and record the number of these containers that were filled. If possible, try to weigh a full container when a scale is available, to find out the average weight, remembering to deduct the weight of the container itself. For example, if rice sacks are typically used, record the number of rice sacks filled, and then when available measure a full rice sack to then calculate the total weight.
8. Calculate the surface area of the plot, subtracting the removed border strip. For example, a 20m by 20m plot would be 18m by 18m after removing the 1m border on each side, yielding a surface area of $324m^2$. Take the total weight of the harvested rice (in kg), divide it by the surface area (in m^2), and multiply it by 10 to get the yield in metric tons per hectare (t/ha):[10]

$$\frac{Weight\ (kg)}{Surface\ area\ (m2)} \times 10 = t/ha$$

3.6.2 Harvesting with representative samples (for larger plots)

To do this method, you will need a precision scale. If one isn't available use the previous method (Section 3.6.1).

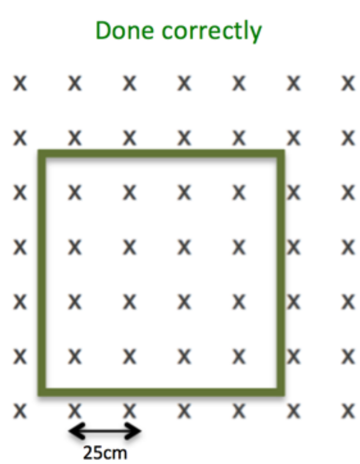
[10] Remember: 1,000g = 1kg = .001 metric ton
100m x 100m = $10{,}000m^2$ = 1 hectare

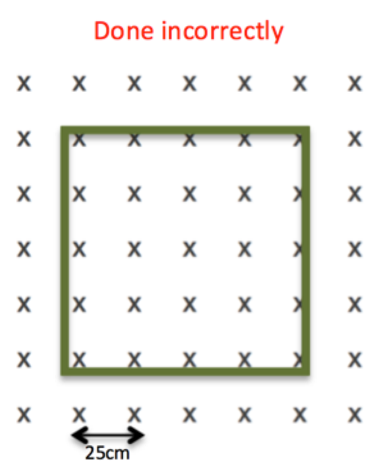
Materials:

- Precision scale (resolution 10-50g or better)
- 1m^2 wood harvesting square (a square wood frame with an **inside** dimension of exactly 100cm on all four sides)
- Moisture meter (optional)
- Measuring tape
- Scythe or machete
- Rice sacks
- Medium size thin plastic bags (if weighing off site)
- Pen and paper strips (if weighing off site)
- Threshing/winnowing materials (same as farmers normally use, e.g., mats, sticks)

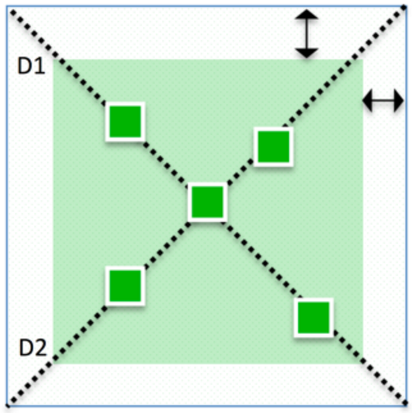
Step-by-step:

1. Follow steps 1-5 from Section 3.6.1.
2. Using stakes and string, mark out the two diagonals of the plot (between opposite corners).
3. Using a custom-made 1m^2 harvesting square, harvest five sample blocks from your plot:
    a. Calculate the number of plants for each block based off the row spacing:
        i. Since the harvesting square has 100cm sides, divide this by the row spacing.
        ii. For a 25cm row spacing, this would mean four plants along each side of the square (100cm / 25cm = 4 plants), for a total of 16 plants to be harvested (4 x 4). Be careful not to accidentally include an extra row of plants. In the example below both fields have a spacing of 25cm between hills; the one on the left is done measured correctly, with the harvesting square placed over 4 rows (16 plants), while the one on the right is placed incorrectly, over 5 rows (a total of 25 plants). If you are using a spacing other than 25cm simply use the formula (100cm / *spacing* = number of rows to include.





    b. Choose your sampling locations:
        i. One block should be in the center, where the two diagonals cross.
        ii. Locate one of the remaining blocks along each of the four diagonal sections radiating out from the center.



c. For each block, carefully place the square over just the number of plants that you calculated (using an incorrect number of plants will dramatically change your yield calculation), and harvest from the base, then set each aside separately.
d. For the control plot, which may not have been planted in lines or with consistent spacing, simply line up two adjacent sides of the square neatly in between two rows (on each side), if possible, allowing the third and fourth sides to fall where they may. Harvest from the base and set each aside separately. If you are harvesting the SRI plots at the same time, take care to not mix the two.

4a. If you have a precision scale and moisture meter with you in the field, count and record the number of plants/hills cut in each square, winnow and thresh the 10 sets of plants, and record the weight and moisture content for each of the 10 sets of plants separately.

4b. If you have a precision scale and moisture meter elsewhere (at the local extension office, for example), then carefully place the 10 sets of threshed and winnowed rice into 10 separate bags, and fill out a label (in pencil) for each bag on a slip of paper and place inside the bag, detailing what plot the sample came from (SRI or non-SRI) and the date of harvest. Weigh and measure the moisture content at the same time, as soon after harvest as possible.

4c. If you have a precision scale but do not have a moisture meter available, dry the rice samples in the shade for 2 to 3 days, with the bag open and in a place safe from rats or birds, and then weigh.

5. Continue with steps 7 and 8 from Section 3.6.1 to measure the weight of the yield and convert this to t/ha.

3.6.3 Simplified yield calculation method

Since one of the goals with an SRI trial is to reinforce farmer-led research and the skills needed to support it, encourage your counterparts to use one of the two previous methods, since these harvesting methods are a useful skill that can help farmers measure their yields in a scientifically rigorous manner. If for some reason they are not able to, then this method is another viable option.

Materials:

- Measuring tape
- String
- Trial log and pencil
- Scythe or machete
- Scale for measuring rice sacks (1kg resolution or better)

- Rice sacks
- Threshing/winnowing materials (same as farmers normally use – mats, sticks, etc.)

Step-by-step:

1. Observe the field, as detailed in Step 1 of Section 3.6.1.

2a. If the plot is small, the farmers can choose to use the entire plot for yield calculations. To do this, remove a 1m border around the plot and set it aside to thresh and winnow separately, then measure the remaining area of the plot. Harvest the rest of the plot, dry the grain in the shade for 1-3 days if necessary, and then thresh, winnow, and place in sacks. Record the number of rice sacks to within ¼ of a sack for partial sacks.

2b. If the plot is too large or has an irregular shape that prevents easy measurement, the farmers can choose a representative area within the plot to sample – as long as the plot itself doesn't show a high degree of variability, which would render the sample unreliable. To do this, select a site within the parcel that looks representative of the average plants in the parcel, staying at least 1m from the edge of the plot. Using a tape measure and stakes, measure out a rectangular plot, preferably 2m or more on each side, and take care to ensure you have right angles at each corner. If you don't have any right angles available, use a 12m length of string or rope to create a 3m-4m-5m triangle – the corner between the 3m and 4m lengths will be a right angle. Stake your rectangle down in between rows, record the dimensions, and harvest all the rice plants within the rectangle. Dry the grain in the shade for 1-3 days if necessary, thresh and winnow, and place into sacks. Record the number of rice sacks to within ¼ of a sack for partial sacks.

3. Using the average weight for a full sack of rice, calculate the yield by multiplying this by the number of sacks, then divide by the surface area harvested, and multiply by 10:

$$\frac{Average\ sack\ weight\ (kg)\ x\ Number\ of\ sacks}{Surface\ area\ (m2)} \times 10 = t/ha$$

4. The farmers can then complete the harvest as they see fit.

Appendix A – Resources

Below is a curated list of resources that will help you and your counterparts make the most of SRI. Additional resources are available in English at www.sriwestafrica.org/resources, and in French at www.sriafriqueouest.org/ressources, and in multiple languages from 50+ countries at www.sririce.org.

Please respect any respective copyrights of each document.

SRI Social Media
Connect with other people across West Africa and the world to ask questions and share resources.

Facebook Groups
SRI West Africa – www.facebook.com/groups/sriwestafrica
Peace Corps SRI – www.facebook.com/groups/peace.corps.sri (worldwide)
SRI Equipment Innovators Exchange – www.facebook.com/groups/SRI.innovators (worldwide)

SRI Manuals and Guides

India – SRI Training Manual (WASSAN) – http://goo.gl/KamS5g
Kenya – SRI Training Brochure (IMAWESA) – http://goo.gl/T2k9lz
Kenya – SRI Training Manual (JKUAT) – http://goo.gl/5wYIKT
Sierra Leone – SRI Training Manual (CRS) – http://goo.gl/k5WlZk
Sierra Leone – SRI Facilitator's Guide (CRS) –http://goo.gl/HzeOov
Zambia – Operationalizing SRI (origin unknown) – http://goo.gl/OSCnLz

Flooded Cellar SRI Training Videos
Flooded Cellar, in collaboration with SRI-Rice and IFAD, created SRI training videos for use in the field as a farmer-to-farmer knowledge sharing tool in East Africa. Available in French and English.

SRI Training Videos

SRI Introduction – The Spread of SRI in East Africa – http://goo.gl/pFe99O (English); http://goo.gl/CqqLrR (French)
SRI Training #1 – Seed Germination and Nursery Preparation – http://goo.gl/eW8HRH (English); http://goo.gl/DHxnXU (French)
SRI Training #2 – Field Preparation and Transplanting – http://goo.gl/oOQDdi (English); http://goo.gl/hv4XFu (French)
SRI Training #3 – Weeding and Water Management – http://goo.gl/qZjD7j (English); http://goo.gl/HHks38 (French)
SRI Training #4 – A New Stick Gives You Blisters – http://goo.gl/DGKJfK (English); http://goo.gl/xSrQyn (French)

Rice Production
Many organizations publish rice production guides for Sub-Saharan Africa. While these guides don't directly reflect the SRI methodology, they are good resources for rice production in general. See also Module 9, from the African Organic Agriculture Training Manual (below), for additional rice-specific production information. AfricaRice maintains an online extension site (www.ricehub.org) dedicated to major rice hubs throughout West Africa, East Africa, and Madagascar, which is a useful resource for identifying locally suitable varieties, as well as information about pests, diseases, fertilization, etc. Keep in mind that the extension advice may at times conflict with SRI guidelines.

Improving Lowland Rice Cultivation – Useful management practices for smallholders in tropical Africa (Agromisa Foundation & CTA) – http://goo.gl/YDtIUg

Growing Lowland Rice (AfricaRice) –http://goo.gl/AMHt9F
Growing Upland Rice (AfricaRice) – http://goo.gl/ADZm6X
NERICA Compendium (AfricaRice) – http://goo.gl/gDSE1X

Soil and Fertility Management

Soil Assessment

Visual Soil Assessment Field Guide – Annual Crops (FAO) – http://goo.gl/J5zZnW
What's the Texture of Your Soil? (SRI-Rice) – http://goo.gl/Weuvnt *(file automatically downloads)*

Soil Organic Matter

The importance of soil organic matter: Key to drought-resistant soil and sustained food and production (FAO) – http://goo.gl/lYUVEu
Invest for 'Life in Soils': 10 ways to make 'living soils' possible (Revitalizing Rainfed Agriculture Network [India]) – http://goo.gl/fJj2v3
Carbon sequestration in dryland soils (FAO) – http://goo.gl/RndWE1

Conservation Tillage/Agriculture

Farmer Field Schools Facilitator's Manual – Integrated Soil, Water, and Nutrient Management in Semi-Arid Zimbabwe (FAO) – http://goo.gl/rvW9Cz
Soil Conservation Techniques for Hillside Farms (Peace Corps) – http://goo.gl/wMymg1
Conservation Tillage in Senegal (Peace Corps) – http://goo.gl/UjrU1I
Manual on Integrated Soil Management and Conservation Practices (IITA/FAO) – http://goo.gl/tBCo8v
No-Tillage Seeding in Conservation Agriculture (FAO) – http://goo.gl/yzxctR
Burkina Faso – Enhancing Crop-Livestock Systems in Conservation Agriculture for Sustainable Production Intensification (FAO) – http://goo.gl/sJSsd8
Conservation Agriculture as Practiced in Ghana (FAO) – http://goo.gl/z7arqD
Scaling Up Conservation Agriculture in Africa (FAO) – http://goo.gl/cUHFFx
Conservation Agriculture Introduction Video (Access Agriculture) – http://goo.gl/zRuxEL

Compost

Composting in the Tropics 1 (HDRA) – http://goo.gl/biqzxE
Composting in the Tropics 2 (HDRA) – http://goo.gl/UFnvcM
Soil Management: Compost Production and Use in Tropical and Subtropical Environments (FAO) – http://goo.gl/OfZr4b
Enriched Compost for Higher Yields (CTA) – http://goo.gl/jRTyxO

Green Manures/Cover Crops

Green Manures/Cover Crops (HDRA) – http://goo.gl/LZqH86
Restoring the Soil: A Guide to Using Green Manure/Cover Crops to Improve Food Security of Smallholder Farmers (Canadian Foodgrains Bank) – http://goo.gl/ZEZMmO

Pest, Disease, and Weed Management

Pest and Disease Control

Natural Pest and Disease Control (HDRA) – http://goo.gl/DvjWyU
Rice Insect Guide (AfricaRice) – http://goo.gl/Gy4iQp
Rice Nematode Guide (AfricaRice) – http://goo.gl/IBnGNi
African Rice Gall Midge (AfricaRice) – http://goo.gl/KdWYUe

Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia (IRRI) [125mb PDF] – http://goo.gl/KxtgNv

Weed Management

Weed Control (HDRA) – http://goo.gl/2kDVIt

Mechanization and Innovation

Mechanization covers everything from simple, handmade tools using found parts, to elaborate motorized tractors. Sometimes the simplest solution is the best, so be creative and experiment freely! The following links provide ideas, inspiration, pictures, and even designs and blueprints for creating tools that will save time, labor, and money.

Facebook Groups

SRI Equipment Innovators Exchange – www.facebook.com/groups/SRI.innovators

Mechanization for SRI

ECHO Asia Notes – SRI Innovations (ECHO) – http://goo.gl/6XGcz9
Cono-Weeder Technical Drawings (AfricaRice) – http://goo.gl/6wUQgS
Curved-Spike Floating Weeder Technical Drawings (AfricaRice) – http://goo.gl/zNS2NV
Grid-Maker Technical Drawings (AfricaRice) – http://goo.gl/clZndX
Metallic Line-Maker Technical Drawings (AfricaRice) – http://goo.gl/c9uMQM
Ring-Hoe Technical Drawings (AfricaRice) – http://goo.gl/hBRexP
Straight-Spike Floating Weeder Technical Drawings (AfricaRice) – http://goo.gl/yx9O9y
Japanese Weeder Technical Drawings (AfricaRice) – http://goo.gl/gHtBgF
Twisted-Spike Floating Weeder Technical Drawings (AfricaRice) – http://goo.gl/bpPt7Y

Dart Transplanting

ECHO Asia Notes – SRI Innovations (ECHO) – http://goo.gl/6XGcz9

Duck Rice Farming Systems

Duck Rice Farming in Japan (Takao Furuno – YouTube video) – http://goo.gl/sFvLkf
Duck Farming Rice – Traditional Wisdom for Sustainable Agriculture (Culture TW) – YouTube video) – http://goo.gl/4tZcSR
Introduction to Integrated Rice-Duck Farming (IRRI) – http://goo.gl/9LDEsE
PARFUND Integrated Rice Duck Farming Facebook Page – http://goo.gl/pyLoUV

Water Management

Water Management

100 Ways to Manage Water for Smallholder Agriculture in Eastern and Southern Africa (SWMnet) – http://goo.gl/vsOQ5w

AccessAgriculture Training Videos

While these aren't specifically about SRI, many of the techniques shown in these videos can be adapted for use with SRI. A partial list is presented below. To access all of their videos, visit the AccessAgriculture website: www.accessagriculture.org.

*Rice Production Videos (see the full list at: **http://goo.gl/jZPDEy**)*

Using the Rotary Weeder in Lowland Rice (Also available in Dagbani and French) – http://goo.gl/zucLkc
Contour Bunds (Also available in 24 other languages, including Dagaare, Dioula, Ewe, Fon, Gourmanchéma, Hausa, Kabye, Mooré, Wolof, Yoruba, and Zarma) – http://goo.gl/fU6x3t

Sustainable Land Management Videos (see the full list here)
Conservation Agriculture Introduction (Also available in French) – http://goo.gl/qS0Cp6

Applying SRI Principles to Other Crops
Ever since SRI first developed farmers have been experimenting with applying SRI principles to other crops, and have achieved great results. While crops like wheat, maize, teff, finger millet, or sugarcane might be expected to respond similarly, the SRI effect has been well documented with such disparate crops as potatoes, turmeric, green leafy vegetables, chickpeas and tomatoes. Using SRI for other crops is now referred to as ***SCI,*** or the System of Crop Intensification, though many refer to specific non-rice crops in the same way as SRI – e.g., STI for the System of Teff Intensification.

The System of Crop Intensification
SCI – The System of Crop Intensification (SRI-Rice & CTA) – http://goo.gl/9P6LQK

African Organic Agriculture Training Manual (FiBL)
This excellent manual, produced by FiBL, encompasses a series of modules covering organic agriculture in Africa. For each module there is a presentation, a trainer's manual, and either farmer's booklets or a flyer. The trainer's manual is a guide to help a facilitator present the slides in the presentation to a group of farmers, with notes for each slide. The farmer's booklets and flyers are meant to be distributed to farmers.

Introduction
African Organic Agriculture Training Manual – Introduction – http://goo.gl/x2KxVV

Module 2: Soil Fertility and Management
Soil Fertility Management – Trainer's Manual – http://goo.gl/R5xdkk
Soil Fertility Management – Presentation – http://goo.gl/4rf4Uh
Soil Fertility Management – Farmer's Booklet – http://goo.gl/tgozf8
Soil and Water Conservation– Farmer's Booklet – http://goo.gl/y9M8qA
Soil Organic Matter Management – Farmer's Booklet – http://goo.gl/FkOeYp
Soil Fertility Supplements – Farmer's Booklet – http://goo.gl/QkyrwX

Module 4: Pest, Disease, and Weed Management
Pest, Disease, and Weed Management – Trainer's Manual – http://goo.gl/F3GVJ3
Pest and Disease Management – Presentation – http://goo.gl/2l1usg
Pest and Disease Management – Farmer's Booklet – http://goo.gl/9C7tsZ
Weed Management – Farmer's Booklet – http://goo.gl/Bky8Bu
Post-Harvest Management and Storage – Farmer's Booklet – http://goo.gl/ajYCo5

Module 9: Crop Management
Rice Crop Management – Trainer's Manual – http://goo.gl/54eHrT
Rice Crop Management – Presentation – http://goo.gl/7ts3U3
Rice Crop Management – Farmer's Flyer – http://goo.gl/yYb97W

Appendix B – Frequently Asked Questions (FAQs)

Is SRI a new variety of rice?

No. SRI is a methodology, and it can be used with any variety of rice including high-yielding varieties, hybrid varieties, and traditional varieties.

Does SRI work the same with every variety of rice?

While all varieties of rice respond positively to SRI management, the level to which they respond varies. SRI primarily changes how plants are managed from germination through the vegetative growth phase. After this, once the reproductive phase has started (when flowering begins), normal plant management can continue. Plants that have a longer vegetative growth phase will have more time under SRI management, and usually show more of a response to SRI. Varieties that are naturally compact and not prone to tillering will still respond to SRI management, but not as much as with varieties that naturally show a higher capacity for tillering and less compact growth.

Does SRI affect the length of the crop's maturation cycle?

Yes. When grown using SRI management, most varieties will see a roughly 1-2 week shortening of their cropping cycle – meaning they'll be ready to harvest 1-2 weeks earlier than they normally would.

Does SRI only work with irrigated rice?

SRI can work with any rice production system where there is not complete inundation throughout the vegetative growth phase. For rainfed upland rice this is certainly not a problem, but for rainfed lowland rice this can be a problem. There are ways to work around this, however. Bunds can be used to prevent or delay some flooding, or farmers can take advantage of plots situated just adjacent to the floodplain at slightly higher elevations, where water is easily accessible but flooding is not a major risk. For rainfed upland rice, incorporating organic matter into the soil, leveling and bunding, and mulching where possible can all help retain soil moisture and create a humid yet aerobic soil environment. For either system, SRI can help minimize drought susceptibility.

Does SRI increase labor costs and time?

SRI does change the timing of labor in many cases, and can change the cost of labor as well. Some of these changes are positive, while some are negative – and in general the question of SRI's impact in labor is very location specific. In many cases if there are negative changes these are mitigated over time – as is the case with improved soil preparation and greater use of organic matter, both of which can improve soil fertility, decrease erosion, and help retain water and nutrients. In the case of labor used to transplant and weed, there is often an initial increase in time spent on these activities, but within two to three seasons farmers may find that they can actually save labor using SRI once they get the hang of it. In many cases where labor costs increase, the increased yields and decreased input costs compensate for the higher labor costs. In some places there is a considerable shift in the timing of labor when switching to SRI, and this may or may not conflict with other labor requirements. When a critical conflict does occur, farmers should explore adjusting the timing of their rice-growing season, if this is a possibility. Keeping track of monetary and non-monetary costs is important to know not only if SRI is cost-effective for farmers in a specific location, but what variations of SRI could be the most effective.

Is SRI organic?

Not strictly, but often yes. Farmers are free to use synthetic fertilizers, herbicides, or insecticides, but are encouraged to see plant and soil health as the basis of plant productivity and resilience. Ideally this would mean using synthetic chemicals sparingly, if at all. Since composting is often new to many farmers in the region, relying solely on organic management can be a large change, and not practical in some cases, but should be aimed for and phased in as is possible.

Does SRI change how pests or diseases affect the rice?

For the most part, rice plots face the same challenges from birds and pests as other fields, though there are some important differences. SRI produces healthier individual plants and improves air circulation, resulting in more vigorous plants and fewer diseases. However, because SRI uses 80-95% fewer plants, losing a small percentage of these to predation or disease can result in a proportionately larger impact on yields. The only time this is likely to present much of a challenge is early on, directly after transplanting or direct seeding. Take care to avoid predation by rats, birds, etc., during the first 10-14 days, when the young plants are still getting established. Don't worry too much if you lose a small number of plants – the neighboring ones will likely be able to fill in the extra space.

What if farmers I work with don't normally grow rice? Can they still try SRI?

Perhaps. Often farmers who are newer to rice are the best able to adopt it, since they have less deeply engrained ideas about how rice should be grown. Rice is very adaptable, and farming with SRI is new for even seasoned rice farmers. In more northern (drier) climates, rainfed upland rice is likely not a possibility without some form of irrigation, but in more humid climates or along river valleys or in seasonal depressions, rice may be a good possibility. Check with local extension agents or nearby communities to see if there is any rice production in the area, and if there are recommended varieties or growing practices. Since SRI changes how the plants are grown, and requires far less water, it could possibly make rice growing feasible in areas where it hasn't historically been considered so.

Can SRI work with crops other than rice?

Yes, and as a matter of fact it can work with a number of crops, including ones that are quite different from rice. When used for other crops, SRI is often called SCI, or the *System of Crop Intensification*. The principles are the same, but the practices are often modified quite a bit. In West Africa SCI has been used with considerable success in growing wheat in the Timbuktu region of Mali and with green leafy vegetables in Nigeria. Around the world farmers have developed SCI methods for crops as diverse as sugarcane, sorghum, teff, maize, mustard, finger millet, turmeric – and even chicken farming. Experiment, and see what happens!

Is plant spacing always 25cm? Is there any reason to increase or decrease the spacing?

SRI is rarely done with less than 25cm spacing, but in certain circumstances where the soil is not particularly rich and the rice variety being used is known to not tiller well at all, a reduced spacing of 20cm or so may work better. The reason for this is that under such conditions the plants may not completely fill the space given to them. For a first trial, it's a good idea to start out with a 25cm spacing and see how it works. If the variety used doesn't fill the space well, consider trying a narrower spacing, and/or increasing the amount of organic matter used, or changing other factors, such as seasonal timing. If, when doing a trial with 25cm spacing, the plants quickly fill the space given to them, then try a wider spacing next time, until you find a spacing which gives the plants more opportunity for tillering.

Appendix C – Comparison Trial Documentation Sheet[11]

Country:	Date:
Village, District, Region:	GPS Coordinates:
	Variety:
Farmer Name:	PCV Name:
Farmer Contact:	PCV Contact:

	SRI Plot	**Control Plot**
CROP		
Soil characteristics		
Soil texture:		
Soil samples taken (yes/no):		
Degraded soil/medium fertile soil/very rich soil:		
Other soil characteristics:		
Dates (period):		
Trial setting		
# of plots/fields:		
Type of trial/experiment (describe – on-farm, on research station):		
Land preparation		
Land preparation – methods, date:		
Crop establishment (Direct Seeding or Transplanting)		
Date:		
Crop establishment method – *direct seeding* – or – *transplanting* (describe methods or tools used, etc.):		
Variety name and characteristics (upland/lowland, source, tillering ability, etc.):		
Seed treatment (yes/no; if yes, what?):		
Nursery seedbed flooded/dry:		
Number of plants/hill:		
Plant spacing (e.g., cm, inches) (between rows, within row, plants/m^2):		
Planted in lines (y/n):		
If transplanted – age of seedling (days):		
If transplanted – type of nursery:		
Amount of seeds used/area (e.g., kg/ha):		
Fertilization		
Organic fertilization (type(s), amount, dates of application, etc.):		
Chemical fertilization (type(s), amount, dates of application, etc.):		
Water management		
Irrigated or rainfed – explain water management system:		
Water control – vegetative phase (y/n):		
Water control – reproductive phase (y/n):		

[11] Developed by Erika Styger, SRI-Rice.

	SRI Plot	Control Plot
Water saving possible? Explain:		
Water saving attained? Estimate or measured amount (e.g., volume, %):		
Weed control		
Mechanical weeding (y/n; weeder type, dates used):		
Other weeding techniques applied (e.g., hand, herbicides; application dates):		
Pest and disease management		
Pest issues (problems, type and efficiency of control methods, dates):		
Disease issues (problems, type and efficiency of control methods, dates):		
Harvest		
Date:		
Yield method and measurements (explain in detail how the yield was determined – m^2 of area, or number of plants harvested, etc. – what types of measurements were undertaken):		
Yield (e.g., kg/ha):		
Number of harvested production units/area (e.g., panicles/m^2, plants/m^2):		
Number of panicles/plant:		
Average panicle size (in mm):		
Weight of harvested unit (e.g., 1000 grain weight):		
Quality of harvested product (describe):		
Other aspects:		
Other effects and results		
Describe other observed results (e.g., drought resistance, grain quality, etc.):		
ECONOMICS		
Costs		
Input costs (seeds, fertilizers, herbicides, pesticides, irrigation water, weeding, gasoline for pump, etc.) (cost/area unit, specifying currency units):		
Revenues		
Revenue from grain (price/unit x yield):		
Revenue from other products (e.g., straw – specify) (price/unit x yield):		
Benefit		
Revenue minus costs per area (e.g., ha):		
Gender implications:		
Environmental implications:		

Appendix D – Harvest Data Sheet[12]

Country:	Date:
Community:	Variety:
Farmer Name:	PCV Name:

SRI Plot			
Plant	# of tillers	# of panicles	Plant height *(cm)*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Control Plot			
Plant	# of tillers	# of panicles	Plant height *(cm)*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Entire plot harvest

SRI Plot		
Panicle	Length *(mm)*	# of grains
P1		
P2		
P3		
P4		
P5		

Control Plot		
Panicle	Length *(in mm)*	# of grains
P1		
P2		
P3		
P4		
P5		

Entire plot harvest

SRI Plot	
Plot size *(m^2)*	
Weight *(kg)*	
Yield *(kg/ha)*	

Control Plot	
Plot size *(m^2)*	
Weight *(kg)*	
Yield *(kg/ha)*	

1m^2 Harvest square

SRI Plot			
Square	# of plants	Fresh weight (g)	Dry weight (g)
S1			
S2			
S3			
S4			
S5			

Control Plot			
Square	# of plants	Fresh weight (g)	Dry weight (g)
S1			
S2			
S3			
S4			
S5			

[12] Developed by Erika Styger, SRI-Rice.

Appendix E – References

AfricaRice (2007). Africa Rice Trends 5th Edition. Cotonou: AfricaRice Center. Available at: www.warda.cgiar.org/publications/2007 Africa Rice Trends 5th edition.pdf

Battaye A, J Kathrine, E Drammeh (2002). Economic impact assessment of the rice research program in The Gambia. Serekunda: National Agricultural Research Institute; Bamako: Institute du Sahel.

FAOStat (2014). FAO Statistical Service. http://faostat.fao.org. United Nations Food and Agriculture Organization.

Gathorne-Hardy A, et al. (2013). A Life Cycle Assessment (LCA) of greenhouse gas emissions from SRI and flooded rice production in SE India. Taiwan Water Conservancy, 61: 110-12. Available at: http://140.112.63.162/pdf/61/61-4-110-125.pdf

Government of Senegal (2010). National Rice Development Strategy for Senegal. Available at: www.riceforafrica.org/downloads/NRDS

Lehmann, J, and G Schroth (2003). Nutrient leaching. In: *Trees, Crops and Soil Fertility* [151-166], CABI Publishing, Wallingford.

Linares, O F (2002). African rice (Oryza glaberrima): History and future potential. Proceedings of the National Academy of Sciences, 99(25), 16360-16365.

Ly P, et al. (2012). The System of Rice Intensification: Adapted practices, reported outcomes and their relevance in Cambodia. Agricultural Systems, 113: 16-27.

Moldenhauer K, N Slaton (2001). Rice growth and development. *Rice Production Handbook*, 7-14. Available at: www.uaex.edu/publications/pdf/mp192/chapter-2.pdf

OECD (2011). Rice crisis, market trends, and food security in West Africa. Available at: www.oecd.org/swac/publications/47853480.pdf

Perricone-Dazzo, L (2014). Farmer centered research on improved cropping systems in the Peanut Basin of Senegal: Peace Corps System of Rice Intensification Campaign. Graduate thesis. Ithaca: Cornell University. Available at: http://sri.cals.cornell.edu/countries/senegal/research/Senegal_PerriconeDazzoMPS0514.pdf

Styger E, D Jenkins (2014). Technical Manual for SRI in West Africa: Improving and Scaling up the System of Rice Intensification in West Africa. Ithaca: SRI-Rice Center, Cornell University. Available at: http://sriwestafrica.org/documents

Thakur, AK, et al. (2011). Effects for rice plant morphology and physiology of water and associated management practices of SRI and their implications for crop performance, PAWE 9:13-24.

Appendix F – Glossary

Aerobic soil – A soil that isn't flooded, with oxygen available for plant roots and soil microbes. See also *anaerobic soil*.

AfricaRice – An international rice research center located in Benin, with a mandate to improve the rice sector in Africa. Formerly called WARDA (the West Africa Rice Development Association), AfricaRice is part of the CGIAR system (Consultative Group on International Agricultural Research). See also *IRRI* and *NERICA*.

Anaerobic soil – An inundated soil, without oxygen present for plant roots and favoring soil microbes capable of anaerobic metabolism. See also *aerobic soil*.

Bas-fonds – The French term for lowland areas, frequently used for lowland rice/valley bottoms that flood seasonally during and after the rainy season. See also *inland valley* and *rainfed lowland rice*.

Bunds/bunding – Small dirt walls, typically 6-18 inches in height, mounded up along the edges of a plot or parcel.

CA – See *Conservation Agriculture*

Cation exchange capacity – The nutrient storage capacity of a soil, as measured by the total amount of negative chemical charge of soil particles. Negatively charged soil particles can hold positively charged plant nutrients through chemical bonds, preventing these nutrients from readily percolating out of the soil. Cation exchange capacity is influenced by soil texture and organic matter content, the latter of which increases cation exchange capacity. Also known as *CEC*. See also *leaching*.

CEC – See *cation exchange capacity*

CGIAR – See *AfricaRice* and *IRRI*

Companion plants/planting – Planting mutually beneficial plants together, which can deter pests and maximize synergies/yields. An example of this is the 'three sisters' system from meso-America, where maize, beans, and squash are planted together.

Cono-weeder – A specific type of rotary weeder that is popular with SRI farmers in certain parts of the world. It's most useful for heavier soils, and often works best for lowland rainfed or irrigated rice systems. Cono-weeders have two weeding wheels, in a truncated-cone shape, with blades sticking off. To keep the weeder moving straight, the cones are lined up in opposing directions. See also *rotary weeder*.

Conservation Agriculture – An agroecological approach to soil conservation that combines three practices: 1) elimination of soil tillage; 2) crop diversification in time (crop rotations) or space (crop associations/companion planting); and 3) continuously covering soils with organic material (mulch or cover crops). Also known as *CA*. See also *companion planting*, *cover cropping*, *mulch*, and *relay cropping*.

Cover cropping – Planting a different crop in between the primary cropping seasons to protect or amend the soil. There must be enough residual moisture or continued rainfall to support this crop. Cover crops may be harvested, tilled back into the ground, or left in place.

Cropping cycle – The length of time from planting a crop until harvest.

Direct seeding – Sowing plants directly in the field, as opposed to sowing first into a nursery then transplanting. Direct seeding can either be done when the soil and seed are dry (known as *dry seeding*); when the soil is wet (i.e., after a heavy rain) but the seeds have not been *pregerminated* (relying on the moisture in the soil to germinate the seeds); or by pre-germinating the seeds before sowing. See also *indirect seeding*.

Dry seeding – Sowing seeds directly into dry soil without *pregermination*. These seeds will sprout when the conditions are right –

typically depending on humidity and temperature. Germination may or may not be uniform.

Eutrophication – An imbalance in aquatic systems caused by excessive nutrients (typically nitrogen and phosphorus), which stimulate dense plant growth, leading to low oxygen levels and animal die-offs due to asphyxiation ("dead zones").

Genotype – The genetic characteristics of a specific variety or species. The term is used here to describe the genetic properties or traits inherent within a plant. See also *phenotype*.

Germination – The start of a plant's growth, when the embryonic part of the grain becomes active. Specific conditions that affect germination vary from variety to variety, but include warm temperatures and humidity. See also *pregermination*.

Grain filling stage – The period after pollination during which the grains fill with a white starchy liquid, which then solidifies to form the grain. Lack of water during this period can result in poorly formed (i.e., small) grains. Birds and insects often attempt to feed on the starch at this stage.

Green manure – Vegetation used for direct application to the field as a fertilizer – often relatively high in nutrients like nitrogen.

Hill – In rice terms, 'hill' refers to an individual spot where one or more rice plants are planted together. In conventional systems, plants are often grouped in clusters of 3 or more; with SRI, plants are placed individually, or in pairs for some rainfed upland systems.

Indirect seeding – Sowing seeds in a nursery then transplanting the seedlings to the field at a later stage. Transplanting allows farmers to better control plant density and ensure even plant establishment – plants uniformly growing in the field at the same age and without empty spots. Transplanting is generally more labor intensive than direct seeding, and in rainfed upland conditions, may be inappropriate, since farmers may have to restart their nursery multiple times if the rains don't fall consistently or start at the expected time. See also *direct seeding*.

Inland valley – Ecologies common in West Africa, with long valleys surrounded by hills or plateaus on each side, and often used for rice production. Can be used for irrigated or rainfed rice production, depending on the infrastructure. See also *bas-fonds* and *rainfed lowland rice*.

IRRI – The International Rice Research Institute, based in the Philippines. The largest rice research institute in the world, with a global mandate, and part of the CGIAR system (Consultative Group on International Agricultural Research). See also *AfricaRice*.

Leaching – Movement of plant nutrients deeper into the soil, making them inaccessible to plant roots. Some nutrients are prone to leaching (such as nitrogen (as nitrate), sulphur (as sulphate), calcium, magnesium, and potassium) while phosphorus is not. The cation exchange capacity (CEC) of a soil, fertilization strategies, and climate all play important roles in determining the rate of leaching in a soil. For more, see Lehmann and Schroth 2003. See also *cation exchange capacity*.

Leveling – The process of making a plot or parcel flat and level, so water does not run off to one side. This is an important component of SRI field preparation.

Lodging – A condition in which plants fall over due to weak plant stems caused by excessive *vegetative growth*, hurting plant yields. Overuse of nitrogen and/or phosphorus fertilizers are a common cause.

Long season variety – A variety with a longer cropping cycle – 120-150 days or more. These varieties are more common in flooded systems (irrigated or rainfed lowland), and are often very well suited to SRI because their longer vegetative growth phase results in a longer period under SRI management, and typically more abundant tillering. See also *cropping cycle*.

Lowland rainfed rice – See *rainfed lowland rice*

Maturation phase – The last of three major phases in the rice cropping cycle. Maturation covers the period after the reproductive phase, when plants have been pollinated and begin grain development. SRI management is not used during this phase – the crop is managed according to conventional practices. Ideally the field is left dry the final 1-2 weeks before harvest. See also *grain filling stage*, *reproductive phase*, and *vegetative growth phase*.

Microbial inoculants – Preparations used to boost the population of helpful soil microbes. In a sense, microbial inoculants are to soil what probiotic foods like yogurt or kombucha are to our digestive systems.

Morphology – The form and structure of organisms. See also *physiology*.

Mulch/mulching – Material used to cover the soil – can be rice straw, agricultural waste product (like sugarcane bagasse), plastic sheets, or cardboard. Mulch helps retain soil moisture and suppress weed growth. See also *Conservation Agriculture*.

NERICA – Short for 'New Rice for Africa,' NERICA is a group of rice varieties produced by AfricaRice. NERICA varieties are fertile crosses of the two domesticated rice species – *O. sativa* ('Asian rice') and *O. glaberrima* ('African rice'). These crosses aim to combine the beneficial yield properties of *O. sativa* with the local adaptation of *O. glaberrima*. NERICA varieties are available for both lowland and upland conditions. See also *AfricaRice*.

Organic matter – Carbon-based plant, animal, or waste matter, such as compost, rice straw, manure, biochar, etc. Organic matter serves multiple functions in the soil, including adding carbon (which is the basic energy source for soil microorganisms), sequestering carbon that would otherwise be lost to the atmosphere and contribute to climate change if burned, retaining water and nutrients in the soil, and contributing to beneficial soil structure. The nutrient content of organic matter varies widely depending on the source. Organic matter rich in nitrogen or phosphorous can burn plants and should be decomposed (composted) either before adding it to the soil or before sowing.

Paddy rice – Harvested rice that has yet to be milled or otherwise processed.

Panicle – The cluster of flowers/grains on a single stem. See also *reproductive phase* and *tiller*.

Phenotype – The growth and shape of a plant, as influenced by environmental factors (as opposed to genetic factors). See also *genotype*.

Physiology – The function of an organism or parts of an organism, and its response to its environment. See also *morphology*.

Polyculture – Growing multiple crops in the same field, as opposed to monocultures, where one crop is grown in isolation.

Pregermination – The process of inducing germination in a seed before sowing it into the field or nursery, typically done through soaking and leaving in a warm but humid environment for 1-3 days. Pregermination helps ensure even plant growth, and gives rice plants a head start over weed seeds.

Puddling – A common field preparation step for irrigated rice where the soil is turned into a deep mud, allowing the field to hold onto water.

Rainfed lowland rice – Rice production located in areas with seasonally high water tables. These are commonly found in inland valleys, river plains, seasonal depressions, and in some coastal zones. Water control can vary from close to perfect to none at all and can often be improved with leveling, bunding, terracing, adoption of drainage and watering canals, etc. Inundation often occurs during and shortly after the second half of the rainy season, though the length and period of inundation vary widely. Localized variation in inundation occurs along the toposequence, and can fluctuate after each major rainfall.

See also *bunding*, *inland valleys*, *leveling*, and *toposequence*.

Rainfed upland rice – Rice systems that are grown solely above the water table, relying entirely on direct rainfall. These systems are the most predominant in West Africa but have the lowest average yields. There is no direct water control, though some measures can be taken to aid in water retention, including leveling, bunding, and additions of organic matter. See also *bunding*, *leveling*, *mulch*, and *organic matter*.

Relay cropping – Starting a new crop before harvesting the previous crop, e.g., sowing beans into a maize field before harvesting the maize. See also *Conservation Agriculture*.

Reproductive phase – The second of the three major phases in the rice cropping cycle, when the plants begin flowering. SRI management is not used during this phase – the crop is managed according to conventional practices. See also *maturation phase*, *panicle*, and *vegetative growth phase.*

Rotary weeder – A type of weeder that's pushed by hand, with rotating parts that uproot and/or chop weeds, sometimes incorporating them into the soil at the same time. See also *cono-weeder*.

SCI – The System of Crop Intensification – i.e., applying SRI principles to other crops, such as wheat, maize, millet, sugarcane, and garden vegetables.

Short season variety – A variety with a shorter cropping cycle, often 90-120 days. Varieties with especially short cropping cycles may be less well suited for SRI, since their short vegetative growth phase reduces the time for SRI management to affect plant growth, especially for varieties known to have a low tillering capacity. These varieties are more common in rainfed upland rice production systems, because they allow farmers to quickly produce a crop and avoid potential problems with the rainy season ending too early or starting too late. See also *rainfed upland rice*, *tillering*, and *vegetative growth phase*.

Soil biological activity – A measure of the active biological component of the soil, which includes microscopic organisms such as nematodes and bacteria, as well as those visible to the human eye, such as earthworms and mycelia.

Surface runoff – Water flowing over the surface of the soil, bringing soil and nutrients (often phosphorous and nitrogen) with it and causing erosion. See also *Conservation Agriculture*, *leveling*, and *mulching.*

Tiller – A shoot (stem) of a plant that is independently capable of producing a panicle of grain. Tillers that do not produce panicles are called 'infertile tillers.' An individual plant can produce multiple tillers, with the number of tillers depending on both the variety of rice used and the conditions. Under excellent conditions, a single plant can produce well over 100 tillers. See also *panicle* and *vegetative growth phase*.

Tillering – The process in which a plant produces new tillers. Rice plants can tiller at an exponential rate if given ideal conditions. See also *tiller* and *vegetative growth phase*.

Toposequence – A gradient measured along the elevation of an area, indicating position relative to the water table, similar to a cross section or elevation diagram. Lower positions along the toposequence are prone to flooding. See Section 3.1 for more information. See also *rainfed lowland rice* and *inland valley*.

Upland rainfed rice – See *rainfed upland rice*

Vegetative growth phase – The first of the three major phases in the rice cropping cycle, when the plants grow in size and number of tillers. Of the three phases, this is the only one in which SRI crop management is different from normal farmer practices. See also *maturation phase*, *reproductive phase*, and *tiller*.

WARDA – See *AfricaRice*

Appendix G – French Terminology

Direct seeding – *semis direct*
Hill (e.g., '1 plant per hill') – *poquet*
Irrigated rice – *riz irrigué (périmètre* when referring to an irrigated rice zone or 'scheme')
Lowland rice – *(riz pluviales du) bas-fonds*
Mulch – *paillis, couvrir de paillis*
Panicle – *épi* or *panicule*
Rotary weeder – *sarcleuse rotatif / houe rotatif*
Spacing (between rows/plants) – *écartement*
Stem – *tige*
System of Rice Intensification – *Système de Riziculture Intensive (SRI)*
Transplanting – *repiquage*
Tiller – *talle*
Tillering – *tallage*
Toposequence – *toposéquence*
Upland rice – *riz pluvial (du plateau)*
Weeding – *désherbage*
Weeds – *mauvaises herbes*

Appendix H – Calculations and Conversions

Conversions

1 hectare (ha) = 10,000 m^2 = 100 m by 100 m
1 metric ton (t) = 1,000 kg

Field calculations

Organic matter application rate = 2-10 t/ha (2,000-10,000kg/10,000m^2)

Nursery Calculations

Nursery size = 1% of field size
Nursery seed use = 85 grams of seed per m^2 of nursery space = 8.5 kg/ha field size
– Add an extra buffer of 15-20% (for a total of 100g per 100m^2 of nursery area / 10kg/ha field size) if you will be using farmer-produced seeds and plan on sorting them to remove nonviable seeds

> *For example: 200m^2 field = 2m^2 nursery = 170 grams of certified seed (or 200 grams of noncertified seed)*

Direct Seeding Calculations

Seed use = 17 kg per ha field size
– Add an extra buffer of 15-20% (for a total of 20kg per ha of field area) if you will be using farmer-produced seeds and plan on sorting them to remove nonviable seeds

> *For example: 200m^2 field = 340 grams of certified seed (or 400 grams of noncertified seed)*

Nursery Calculations

Calculating the yield when harvesting the entire plot:

$$\frac{Weight\ (kg)}{Surface\ area\ (m2)} \times\ 10 = t/ha$$

Calculating the yield when harvesting the entire plot without a scale, use the average weight of the sacks (or other container if not a sack) used to store the harvest (commonly 100k or 50k sacks):

$$\frac{Average\ sack\ weight\ (kg)\ x\ Number\ of\ sacks}{Surface\ area\ (m2)} \times\ 10 = t/ha$$

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