Benefits of the System of Rice Intensification (SRI) and associated practices
1. Increased Yields for Food Security

SRI enhances rice plant phenotypes to achieve significantly higher crop yields (Styger and Uphoff, 2016). As with any biological process, each variable (water, soil biota, climate, seasonal variance, etc.) plays a considerable role in the outcomes so that data on increased yield can vary. However, it is widely agreed that SRI increases grain yield by at least 20-50% (ibid.; Thakur et al. 2021; Africare/Oxfam/WWF, 2010), with some studies reporting increases from 50% up to 100% or more (Hawken, 2017; Styger and Traoré, 2018; Africare/Oxfam/WWF, 2010, p. 32).

In addition to giving greater paddy yield, SRI methods increase grain quality. The final outturn of milled polished rice after paddy grains are milled is usually around 10% higher than from conventionally-grown paddy rice, due to the fewer unfilled grains and the less breakage during the milling process (SRI-Rice, 2022).

SRI also enhances the micronutrient content of rice grains with increased levels of iron, calcium, manganese, and zinc due to enhanced uptake into the plant (Thakur et al., 2020). There are also lower levels of arsenic and mercury in the grain, by up to 90%, due to alternate wetting and drying (Ishfaq et al. 2020). With increased grain quality, yields, and enhanced nutritional value, SRI methods significantly improve both the quality and quantity of rice production. This makes SRI a practical, low-cost innovation for improving food security (FAO, 2016, pp. 44-47).

2. Increased Income for Farmers

With SRI, farmers' net income from rice production increases by more than solely the yield increase, thanks to lower input costs, notably seed, energy and synthetic chemical fertilisers and pesticides.

The economic increases range from 40%-70% (Nayar et al., 2020; Styger and Traoré, 2018; Mishra et al., 2021) up to 250% (Behera et al., 2013).

With energy and agrichemical costs at higher levels, and water increasingly scarce in many rice-producing regions, the economic case for SRI has strengthened further.

3. Climate Resilience

Production impediments such as pests, diseases, and climatic hazards like droughts and storms, play a significant role in crop loss and will increase as the impacts of climate change continue to worsen. The communities most vulnerable to severe climate impacts are those that are already marginalised (IPCC, 2022). Farmers need to adapt their practices to make their crops more climate-resilient and to safeguard their environmental resources.

SRI provides climate-resilience through reduced water requirements for cropping (Jagannath et al., 2013); increased resistance to biotic and abiotic stresses (Thakur and Uphoff, 2017); as well as increased resilience to cold temperatures, storm-damage, and pests and diseases (Adhikari et al., 2018; Thakur et al., 2021).

Further, with less reliance on the use of synthetic chemical inputs, the beneficial soil biota is more abundant and diverse adding to the resilience of the whole agricultural system. A study in India showed that per unit of water transpired, SRI-grown plants photosynthesize
more than twice as much carbon dioxide from the air, converting it into carbohydrates and producing ‘more crop per drop’ (Thakur et al., 2010). This will become increasingly important in the decades ahead.

SRI practices also improve resistance to many of the pests and diseases that afflict rice plants (Chapagain et al., 2011). This increased resistance and resilience to weather, pests and disease results primarily from the changes in the plant’s characteristics induced by SRI practices (Thakur et al., 2016). Plants’ root systems under SRI management grow larger, deeper and denser, anchoring plants better and supporting more microbial activities in the rhizosphere. By accessing more water and nutrients, enlarged root systems also play a role in reducing the incidence of pests and diseases (Rajkishore et al. 2015; Randramiharisoa et al. 2006). SRI practices increase silica in the rice stalks and leaves, making it harder for chewing insects to penetrate them (Randramiharisoa et al. 2006). The increased space between plants creates less favourable microenvironments for many pests and diseases, and SRI’s shortening of the crop cycle reduces plants’ exposure to biotic and abiotic stresses (Thakur and Uphoff, 2017).

When SRI is combined with practices such as low/no till and direct seeding, the soil is left mostly undisturbed, supporting the proliferation of soil biodiversity. Maintaining organic soil coverage through mulching and/or cover crops also contributes to increase SOC and therefore to enhance soil biological activities. Crop diversification also provides conducive environments for diverse soil biota which enhance the resilience of the whole farming system.

These combined and holistic approaches lead to ameliorated soil health and the enhancement of active soil biology which creates an improved environment for pervasive root systems to absorb nutrients and increase plants’ production. Most importantly, healthy and biologically active soils ensure long term sustainability and resilience to stress of the whole farming system.

4. Water Reduction

Higher yields are achieved with a reduction in water consumption through SRI practices (Jagannath et al., 2013; Wu et al., 2015). A meta-analysis of 29 published studies from eight countries covering 251 comparison trials found that SRI methods saved on average 3.9 million litres per hectare (7.2 million litres compared to 11.1 million) when compared with conventional management for irrigated rice production (Jagannath et al., 2013).

By increasing grain yield and reducing water input, SRI methods improved total water use efficiency by 52%, and irrigation water use efficiency by 78% compared to conventional crop management.

When SRI and Conservation Agriculture practices are combined, soil water-holding capacity is increased and evaporation reduced, further reducing water consumption.

5. Greenhouse Gas Reductions

SRI practices have been shown to lower greenhouse gas (GHG) emissions from rice cultivation in a variety of countries, e.g., Nigeria, Vietnam, Laos, Cambodia, Thailand, India, and Korea (Bello et al., 2022; Mishra et al., 2021; Nirmala et al., 2021; Gathorne-Hardy et al., 2016; Choi et al., 2014). SRI methods influence GHG emission reduction through several
processes.

Gathorne-Hardy et al. (2016) undertook a comprehensive analysis of SRI impact on all three GHGs in India. They calculated a 40% net reduction in Global Warming Potential (GWP) per hectare, and a 60% reduction in net GHG emissions per kg of rice as more rice was produced per unit of land and other inputs.

A recent study conducted on an ongoing programme in Nigeria (Bello et al. 2022) indicates that the adoption of SRI led to a decrease in emissions of methane, carbon dioxide, and nitrous oxide across all the selected locations. In some areas SRI practices reduced methane emission by 41%. Encouragingly, nitrous oxide emissions were also reduced, as the shift from inorganic to organic fertilisation outweighed the increase from moving from continuously flooded to intermittently flooded rice fields.

SRI effects on GHG emissions are discussed in the following sections.

(a) Methane (CH$_4$)

SRI water management practices, named alternate wetting and drying (AWD), have significant potential to mitigate methane by stopping the continuous flooding of rice fields.

By reducing the anaerobic conditions of soil which support the proliferation of methanogens, SRI methods decrease the production of methane while microbes that consume methane (methanotrophs) thrive in aerobic, unflooded soil (Singh et al., 2021; Thakur et al., 2014; Yan et al., 2009; Rajkishore et al., 2013).

The magnitude of any reduction of methane emissions is highly context-dependent due to variances in soil type, soil pH, soil moisture, temperature, soil organic carbon content, growth stage and the complex interactions of all these variables (Setiawan et al. 2014; Yan et al., 2009; Thakur and Uphoff, 2017; Malyan et al., 2016).

AWD by itself has been reported to reduce methane emissions ranging from 48% (Richards and Sander, 2014) to 70% (Hawken, 2017), and up to 85% or more (Islam et al. 2020; Lahue et al. 2016).

AWD is not the only SRI practice that reduces methane emissions. Applying less or no inorganic nitrogen (N) fertilisers to rice paddies also reduces methane emissions (Wu and Uphoff, 2015). Rajkishore et al. (2013) report that 19-63% of the reductions in methane emissions recorded under SRI management derive from the practice of active soil aeration through the use of simple mechanical cono-weeders that break up the soil’s surface as they eliminate weeds.

(b) Nitrous oxide (N$_2$O)

There can be some offset against methane reduction by an increase in nitrous oxide, a greenhouse gas 25 times more potent than methane and produced by microbial activity in unflooded soil. The adoption of SRI water management is likely to increase N$_2$O, but most evaluations have shown that SRI increases in nitrous oxide are minor (Gathorne-Hardy et al., 2016), or there may even be decreases (Bello et al. 2022).

What predominantly drives the generation of nitrous oxide is an abundance of nitrogen in the soil, and SRI’s reduction or avoidance of synthetic nitrogen fertiliser decreases the
substrate for nitrous oxide emissions.

A global meta-analysis found that nitrous oxide emissions from organically-managed soils are lower (by 492 ± 160 kg CO₂ eq. per hectare per year) than from soils managed with non-organic amendments (Skinner et al., 2014). A fully-organic implementation of SRI is therefore unlikely to result in increased nitrous oxide emissions.

(c) Carbon dioxide (CO₂)

The contribution of SRI to reducing carbon dioxide emissions is associated with the indirect GHG emissions resulting from the production, transportation and distribution of inorganic N fertiliser and agrochemicals (Lal, 2004) as well as fossil fuel consumption in irrigation.

Gathorne-Hardy et al. (2016) estimates that with irrigation use reduced by 60% per hectare, SRI lowered the consumption of fossil fuels by 74% per hectare.

6. Carbon Sequestration

The approximately 160 million hectares cultivated with rice on a global scale have great potential for absorbing and storing CO₂ from the atmosphere (IPCC, 2022; Lal, 2004). Rice soils are very important sites for global carbon cycling because of their capacity to retain high amounts of resilient carbon (Rajkishore et al., 2015).

Plants photosynthesise CO₂ and put the carbon products below-ground as root growth or as exudates. Under SRI management, rice plants have greater root length and density. For example, in an early study in Madagascar, it was found that the root biomass of SRI plants was 2.3 times higher at 30-40 cm depth and 3.8 times higher at 40-50 cm compared with the same variety grown conventionally in the same soil and under the same conditions (Barison, 2003).

The proliferation of root growth under SRI management promotes an expansion of the rhizosphere and enhances microbial abundance and activity. Studies show the beneficial effect of SRI practices on the prosperity of soil microbes; ICRISAT and other scientists in India found that the microbial biomass carbon in SRI soils is up to 41% higher than under conventional rice-growing practice (Gopalakrishnan et al., 2014; Rupela et al., 2006).

In addition to that, when SRI is implemented with Conservation Agriculture principles, the soil quality is further enhanced. Reduced soil disturbance from no/low tillage supports the proliferation of soil biodiversity while the permanent organic soil coverage achieved through mulching and/or cover crops also contributes to adding carbon into the soil therefore enhancing its biological activities. Crop diversification also provides a conducive environment for diverse soil biota which enhance the proliferation of active root systems. With more root biomass, more carbon is put into the soil as roots and exudates.

In addition to reducing GHG emissions, these agroecological practices can help to sequester more carbon in the soil, resulting in an important mitigation of the negative impact that rice production has on climate.

7. Benefits for Women

SRI provides benefits especially for women who play a major role in rice cultivation globally,
providing up to 80% of the labour invested in growing rice (Vent et al., 2016). Weeding rice crops by hand, traditionally done by women in most countries, requires long hours spent in uncomfortable bent postures in flooded, muddy paddy fields with conventional rice cultivation; and also exposes the workers to toxic chemicals.

Using a simple mechanical weeder reduces labour time and allows an upright posture, thereby avoiding long exposure to unsanitary conditions in the field and reducing drudgery. A study in India found that the use of the mechanical weeder alone reduced women’s labour requirements by up to 76% per hectare (Mrunalini and Ganesh, 2008).

Women avoid prolonged water exposure and water-borne disease vectors by working in SRI fields that are not continuously flooded and managed with less or no use of agrochemicals. SRI further lessens women’s labour requirements by greatly reducing plant density (by 80-90%), lessening the size of the nurseries needed for SRI seedlings and reducing the time required to manage them. Transplanting can be completed more rapidly and easily as SRI seedlings are smaller, lighter and fewer (Vent et al., 2016; SRI-Rice, 2014). Reducing women’s labour time gives them more time for activities of their choice, which can result in diversified incomes and better outcomes for the family (Africare/Oxfam/WWF, 2010; Resurreccion et al., 2008).

Enhanced equity and status for women is a further benefit of SRI. An Oxfam study in Vietnam found that 70% of the participants in Farmer Field Schools (FFS) learning about SRI were women. With women acting as farmer-leaders, women’s status and voice within their families and communities were enhanced.

8. The Four Principles of SRI and Their Benefits

(a) Early, quick and healthy plant establishment

Laulanie (1993) observed that the transplanting of young seedlings can lead to more robust and productive rice plants. This is because of periods of activity and inactivity, called phyllochrons, which are associated with different growth and rest stages. The transplanting of rice seedlings between their 2nd or 3rd phyllochron of growth, roughly translatable to between the 5th and 15th day, is done within the period of rice plant dormancy, a window of opportunity during which root trauma is minimised. When growth resumes after transplanting, phytomer production is accelerated. When rice is transplanted after the 15th day, there is not as rapid, or as much growth (Uphoff, 2015), as has been validated empirically by Uphoff and Randriamiharisoa (2002).

(b) Reduced plant density

The high plant density typical of conventional rice agriculture of 3-6 plants per hill results in reduced space for root system growth and in less sunlight that can reach the lower leaves of the plant. Data gathered by Anischan Gani in 2002 at IRRI in Sukamandi showed that with the narrow spacing typical of conventional rice cultivation, insufficient sunlight reaches the lower leaves to support photosynthesis (Uphoff, 2015). This means that these leaves take energy from the plant rather than providing energy. As these lower leaves provide most of the energy to the rice roots, tightly packed rice plants reduce the growth and functioning of
their root systems. When there are fewer plants, and all the leaves are active in
photosynthesis, with the root systems well supplied with photosynthates, then each plant
will have more tillers, with more abundant and heavier grains compared to rice plants grown
traditionally. The increases in yield more than compensate for the reduction in plant density
(Thakur et al., 2010).

(c) Improved soil conditions through enrichment with organic matter

Although the use of chemical fertilisers demonstrates higher yields than without, the best
results for SRI have been observed when soils have been fertilised with organic matter.
Organic matter is valuable for its nutritional content but also for how it can improve the
structure and functioning of soil systems. Soils are able to hold more nutrients in the rooting
zone, releasing them when needed by the plants (Uphoff, 2015).

(d) Reduced and controlled water application

As explained in Section 5, the implementation of AWD leads to significant reductions in
methane emissions from rice paddy fields, because of a reduction in anaerobic soil
conditions. Value chain emission reductions contribute to decreased carbon dioxide
emissions, while increases in soil carbon sequestration are also seen because of increased
root length and density, as explained in Section 7.

9. References

productive, resource-conserving, climate-resilient, and sustainable agriculture:
Experience with diverse crops in varying agroecologies, *International Journal of
Agricultural Sustainability*, 16:1, 1–28. Available at: DOI:
10.1080/14735903.2017.1402504

Tropics, Hyderabad, India.

Intensive (SRI) Cultivation Systems in Madagascar, MSc dissertation, Cornell University,
Ithaca, NY.

Community Institutions in Bihar, India*, World Bank, New Delhi. Available at:
0P09000 30Note10Box0374379B.pdf [Accessed 20/04/2022]

Monitoring for the System of Rice Intensification (SRI) Under Rainy Season for the
LINKS-SRI Project in Kano and Jigawa States. Centre for Dryland Agriculture, Bayero
University.


229, 30–39. Available at: DOI: 10.1016/j.agee.2016.05.020


A4.pdf [Accessed 08/04/22]


41. Thakur, A.K., Uphoff, N., (2017) How the system of rice intensification can contribute to


