Chapter 1: WHAT MAKES THIS STORY IMPORTANT

This book presents an account that could become one of the most significant stories in this century, or it could turn out to be simply a very important story. Depending on when one chooses to date its start, this story began some 20, 30, 40, or even 50 years ago. But it began in earnest about 20 years ago and is continuing, and it could go on for another decade or several.

This chapter reviews why the SRI story is important, and the next one lays out how the story will be told, as a memoire of something, not of a person. This is kind of memoire is unconventional, but so is the innovation that it reports on and memorializes. SRI's novelty justifies an unusual approach to story-telling, about which more will is said in the next chapter.

This memoire will capitalize on technical possibilities for the dissemination of knowledge that books did not have in previous decades, making this report freely available electronically to anyone interested.

Why should SRI be of interest to readers? This is the question to begin with.

- How many innovations can increase the output of food by *reducing* production inputs and by *lowering* production costs, rather than by expanding them? SRI practices raise crop yields not just by increments, but often by multiples
- What other agricultural inventions can deal with the afflictions of hunger and poverty at the same time at the same time it counters climate change and buffers crops against its stresses and hazard?
- How often can innovations improve the nutritional quality of food as well as its quantity, while ameliorating the conditions of work and quality of life for women? Women endure a disproportionate share of the disease and discomfort associated with producing rice, our world's most important staple food, which provides 20% of humankind's caloric needs.

Any innovation that can offer such large and diverse benefits is certainly remarkable, especially if it is based more on the spread of knowledge, not requiring capital expenditures.

The System of Rice Intensification, known as SRI, can be considered as a technology, but here it is characterized as an innovation rather than as a technology. Why? Because it has more elements and more implications than are usually associated with the term 'technology.' Any new technology is, of course, an innovation; but innovations can be more than technologies. SRI has been described variously as, for example, a movement[1], or paradigm, or even as a philosophy.[2] These things are more than any typical technology.

At its core, SRI is an idea, or a suite of ideas, that originated from the work and thought of Fr. Henri de Laulanié, a French Jesuit who lived half his life in Madagascar. But SRI has taken on a life of its own as it has evolved and diversified in the past several decades. Speaking broadly, SRI represents a confluence or congruence of insights, concepts, practices, proponents, and experiences, meeting a range of contemporary needs.

The understanding and acceptance of SRI has been somewhat slowed by people's inclination to try to pour its 'new wine' into the familiar 'bottle' of technology, specifically the kind of agricultural technology associated with the now-well-known Green Revolution. Such a conflation causes confusion because many of the ideas and practices of SRI are contrary to those that constituted the Green Revolution.

The Green Revolution sought to increase the world's food production first by breeding and planting what were called 'improved' varieties of cereal crops, and then by increasing the use of synthetic fertilizers and chemical crop protection. Larger volumes of water were also needed and consumed. It surprises most people to learn that SRI does not rely on new varieties or on agrochemical inputs, and it succeeds with less rather than more irrigation water, which is increasingly scarce. SRI's approach is thus very different from that of the Green Revolution.

Green Revolution practices were broadly successful in the latter third of the Twentieth Century. However, they have entailed substantial economic and environmental costs. Moreover, they have been losing momentum over the past few decades.[3] It has been quite a revelation for farmers and scientists to learn that SRI methods can give even better results than those from Green Revolution technology with fewer economic and environmental costs.

Thanks to SRI we now know that farmers can get higher crop yields plus other benefits just by making certain changes in their methods of cultivation, such as stopping the age-old practice of growing rice in continuously-flooded paddy fields.[4] Also, SRI shows that higher yields can be achieved by greatly reducing the density of plants in rice fields, by 75% or more. This seemed implausible until such results were demonstrated again and again, with scientific research subsequently validating them.

Very importantly, these insights do not apply only for rice cultivation. Farmers have been able to make better, more productive use of their available resources by adapting the ideas and methods of SRI developed for irrigated rice to many other crops (Chapter 13).[5]

The counter-intuitive results of SRI – getting more output with fewer production inputs -- are achieved by drawing on two sources of productivity that were almost completely ignored by the Green Revolution: plants' root systems (Chapter 4), and soil biology (Chapter 5).

SRI methods, especially when taken together, enable rice plants to grow larger, healthier, longer-lived root systems at the same time that they promote more abundant and diverse life in the soil. Better root systems and more abundant soil organisms together support the emergence and growth of more tillers (stalks), with more of the tillers producing panicles (heads) that form and produce rice grains; and these grains in turn are more numerous in each panicle and also often heavier. These are the elements that contribute to having higher yield.[6]

The value of having more biodiversity and biological activity in the soil is becoming more understandable as we learn more about called the soil-plant microbiome.[7] This is similar to the human microbiome which we now know contributes greatly to our own health and well-being.[8] SRI's attention to root systems and to soil biology is of broad relevance,[9] and it fills a major gap in the thinking and strategy of the Green Revolution, a gap that is becoming more and more evident.

The importance of roots and the impact of modified soil and crop management can be seen very easily. The first picture below was sent to Cornell from Cuba in 2003. It shows two rice plants of the same age and same variety, each endowed with the same genetic potential. However, the plant on the right has 43 tillers, while the one on the left has only 5. As significant as this difference in the number of tillers are the obvious differences in the size and color between the two respective root systems.

The seeds for both plants were sown in the same nursery on the same day. But the plant on the right was grown with SRI methods while the plant on the left was grown according to the farmer's usual practices. The contrast between the two plants makes tangible the kind of impact that altering a plant's growing environment, both above and below ground, can have on its growth and performance.

The second picture, sent from Liberia in 2014, shows the same kind of effect observed in a very different setting, in West Africa. Again, both plants were grown from the same variety of seed, so they had the same growth potential. The disparity in their sizes and vigor can hardly be accounted for by the fact that the SRI plant on the right was planted 3 days before the conventionally-grown rice plant seen on the left.

On left, Cuban farmer Luis Romero holds two rice plants of the same age and same variety (VN2084). Both were started in the same nursery at the same time, but the plant on the right with 43 tillers was transplanted when only 9 days old into an SRI-managed field. The other plant, with 5 tillers and still considered a seedling, was removed from the nursery for this picture at 52 days of age. In Luis' region, transplanting is usually done between 50 and 55 days.[10]

On right, Edward Sohn in Grand Gedee county of Liberia shows two contrasting rice plants of the same variety. The plant on the right was grown in an SRI plot while the other on the left was raised by Edward in a nearby field with his usual practices.

Such large and dramatic differences are not always achieved with SRI management. But these pictures show how simple changes in crop management can elicit more productive, more robust plants, taking fuller advantage of their genetic endowment. The picture below sent from Iraq in 2007 shows how rice researchers in that country observed remarkable improvements in rice plants' growth that could be evoked by changing cultivation methods. These and many other pictures will included as a part of the SRI story because SRI is a very visual subject.

This picture was sent to Cornell from the Al-Mishkhab Rice Research Station near Najaf in Iraq in 2007. Researchers there were evaluating the effects of SRI practices on different varieties of rice. Each pair of side-by-side plots was planted with the same rice variety. In each pair, the left-hand plot was managed with SRI practices: young seedlings, wide spacing, organic fertilization, etc. Unfortunately, because of close proximity, water management practices could not be varied much. However, the effect of using most if not all of the SRI practices was very evident.

The precepts and practices of SRI originated from the observations, insights and experimentation of a remarkable French priest-agronomist, Fr. Henri de Laulanié, S.J., while he lived and worked with farmers in Madagascar for 34 years, as discussed in Chapter 3. The methodology that he developed was intended to enable resource-limited farmers to utilize their available resources, their land, labor, seeds, water, and capital, more productively for the benefit of their families and the natural environment.

The advantageous effects of SRI management have now been observed in more than 60 countries which together produce about 98% of the world's rice.[11] So SRI has been launched around the world by the far-flung efforts reported in Part III of these memoires and in mini-memoires. Probably more than 20 million households are benefiting from the use of SRI ideas and methods, with this number growing every year.

This means that the lives of as many as 100 million people are already being improved through SRI knowledge and practice. However, the story of SRI is not widely known, and hundreds of millions of persons have yet to benefit from the diffusion of SRI ideas and methods, even though these are made freely available, not owned or controlled by anyone. We hope that these ideas and their benefits can become more widely known and utilized.

GLOBAL CHALLENGES TO BE DEALT WITH

SRI innovation addresses a number of the great and grave challenges that face humankind in this 21st century:

- Reducing the **continuing hunger and poverty** in this world which are not only unjust and immiserating, but also sources of instability and turmoil;
- Enabling farmers to adapt to and even to help mitigate the disruptive forces of **climate change**;
- Making the **world's food supply** greater and more stable, sustainable and cheaper;
- Contributing to **gender equity**, to **soil health**, and to **human health and nutrition**;
- Supporting the **conservation of biodiversity** both above and below ground; and
- Charting a **more participatory, self-reliant path to development** because SRI productivity gains are achieved through collaborative action and without proprietary control of the innovation.

Certainly, SRI ideas and practices cannot counter debilitating problems like armed conflict or institutional incapacity. But it will be more difficult to deal with these misfortunes when hunger and poverty are dire, and when the lives of millions of people are existentially insecure. The multiple benefits listed above probably sound like too much to expect from any single innovation. But as will be seen, all of these effects and more are being achieved to some or a great extent, quickly and at low cost, just by making certain changes in current agricultural practices.

In decades past, what is referred to as 'modern agriculture' has served most if not all of the world's people quite well. However, in this present century we must produce more food under different conditions than prevailed in the last half of the 20th century. Agriculture needs to progress into the next stage in its millennia-long ascent from hunting and gathering to support still-growing human populations, promoting the health, vitality, security and dignity of billions of people.

This must be achieved while we cope with diminishing arable land per capita, with scarcer and less reliable water supplies, with changing and more constraining climatic patterns of temperature and rainfall, with degrading soils, with heavy energy costs, with growing concern for environmental quality and for sustainability, and so forth.

This memoire of SRI is presented as a story rather than as a scientific treatise, but there will necessarily be some discussion of scientific issues, explanations and controversies, some of them quite dramatic. All should be understandable without much scientific schooling (the author is neither an agronomist nor a microbiologist by profession, but rather by training a social scientist), and all are relevant for addressing the challenges listed above.

The story of SRI is first and foremost about people, and for people. However, the realm of biology, of which our human species is an important part, is an intrinsic and integral part of the story. The melding and interdependence of the biological and the social, the material and the mental, the general and the personal, is a constant theme throughout this story. We will also see how the institutions and practitioners of science have often not lived up to their own standards. It is important to understand this clearly because humankind now needs successful scientific endeavor more than ever before.

BENEFITS OF SRI

For readers to decide whether reading this story of SRI is worth their time and effort, they should know something at the outset, at least in brief, about the benefits being derived from the ideas and principles of SRI. These principles get applied through specific practices that are be adapted to local conditions, socioeconomic as well as biophysical. In the course of telling the SRI story, more evidence will be offered for all of the benefits reviewed below. Here, summarized in a few pages, are advantages that can be achieved from the knowledge and application of SRI, with a discussion also of the costs of SRI following.

***Increased crop yield*:** The most easily demonstrated benefit from SRI principles and practices is the higher food production achievable from growing practically any variety of rice -- old or new, unimproved or improved -- on just about any soil. The increases of 20-50% and often 100% or more, result from SRI methods' facilitating greater root growth and their mobilizing the services of the soil biota. In SRI cultivation, the amounts of seed, water, fertilizer and agrochemicals that farmers use are all reduced, while the addition of organic matter to the soil is increased. At first, more labor may be required until the methods are mastered, as discussed below. But for most rice farmers, the need for labor is reduced with SRI, immediately or within a year or so. This is a big advantage, especially as yields are increased in the process.

In Chapter 10, we will consider the 'super-yields' occasionally reported with SRI management and the controversy that these have engendered. SRI yields sometimes surpass 20 tonnes of paddy rice per hectare, while the world's average paddy yield is about 4.5 tonnes per hectare.

These outliers are not flukes or accidents, although they also are not the norm. They represent the results of best use of SRI practices under well-managed growing conditions with favorable weather. In some sense, they represent a kind of sideshow, because center-stage should be reserved for the changes achieved in farmers' average yields.

Average increases are more important than top yields because it is averages that increase food availability and that can make the majority of people better off. At the same time, much can be learned from exceptions, from 'desirable deviance' from the norm. Outliers, therefore, should not be dismissed without examination, especially if they are much above the average.

Lower costs of production and more net income for farmers: SRI methodology starts by sharply reducing plant density, cutting the number of rice plants per square meter by as much as 90%. Single seedlings are transplanted in a square pattern with wide spacing between them, rather than helter-skelter or in rows. Reducing seed requirements immediately reduces farmers' costs of production.

Then farmers use less or even no chemical fertilizer and agrochemicals, relying instead as much as possible on compost or other forms of organic material that enhance their soil's fertility and on non-chemical means for crop protection. Farmers' applications of water are greatly reduced because rice paddies are no longer kept continuously flooded. When these changes cut farmers' expenses, their incomes are raised by a larger percentage than their yield increases.[12] Achieving greater production with lower costs lessens poverty at the same time that it reduces hunger.

Less reliance on purchased inputs and agrochemicals: Reducing farmers' dependence on agrochemical inputs, particularly fertilizer and crop protectants, has benefits beyond its economic advantages. For one thing, this makes SRI more accessible to poor farmers than are most conventional agricultural technologies which require often heavy expenditure. Farmers do not need to take out loans for SRI cultivation or to incur debts that jeopardize their meager assets if there is crop failure. At the same time, natural ecosystems benefit from having less run-off of inorganic nitrogen and phosphorus from rice fields into groundwater and river systems. Both soil health and water quality are enhanced, and this contributes to a less-polluted, more biodiverse natural environment.[13]

Saving of water: Irrigated rice production consumes between a quarter and a third of the world's developed freshwater supply. When rice paddies are no longer kept continuously inundated, this reduces rice farmers' water requirements in the range of 20 to 50%.[14] Such saving will become ever more important in the decades ahead as climate change alters the amount, reliability and distribution of rainfall, and as soil water tables descend lower and lower from the surface. Growing more rice with less water is becoming imperative, with farmers producing 'more crop per drop.'

Resilience to hazards of climate change: Growing crop plants with better root systems and making soils better able to absorb and retain rainfall means that these crops become more resistant to drought and storm damage (lodging), hazards that will increase with climate change. Also, there is evidence that plants grown with SRI methods are more tolerant of temperature extremes and have more innate resistance to insect pests and diseases. SRI management thus makes crops less vulnerable to various impacts of adverse climate.[15] **[delete line below]**

This effect is visible in the pictures below and in their captions. While these effects are most evident and dramatic with rice production, there are similar effects for adapting SRI ideas and techniques to producing other crops like wheat and finger millet, by promoting better root growth and more life in the soil. **[make below into a box]**

Rice field comparisons in Sri Lanka and Indonesia showing the resistance of SRI crops to the hazards of weather and pests that are associated with climate change. In both pictures, the SRI-managed fields are on the right.

On left, these two fields planted with the same variety of rice had experienced the same water shortage after the irrigation reservoir serving them had dried up 3 weeks earlier. Plants in the field on left which had been continuously flooded had less root growth as a result of inundation. The SRI rice plants on the right were withstanding the effects of drought because of their deeper rooting, yielding a normal harvest.[16]

On right, the field on the left was planted with a 'modern' rice variety and received recommended fertilizer inputs, while the one on the right was planted with a local variety and cultivated with organic SRI methods, including use of compost. When both fields were hit by a brown planthopper pest attack and then by a tropical storm, plants in the field on the left were badly affected by the insects and then by lodging, resulting in little yield. The plants on the right gave the farmer, Miyatty Jannah, who took this picture and passed it on to the author, a yield of 8 tonnes per hectare. Differences this stark are not often observed, but they show how much effect making modifications in crop management can have.

Shorter cropping cycle: SRI-grown rice plants are generally found to mature more quickly after transplanting, often by 5 to 15 days (Chapter 10). Shortening crops' time in the field reduces their exposure to climatic and pest hazards, especially at the end of the growing season.[17] Earlier harvesting also makes land productivity *per day* even greater than the yield increases per hectare, reported above. Acceleration of rice crop growth can enable farmers to plant an additional short-cycle vegetable crop that augments household income and nutrition where weather and soil-moisture conditions permit.

Reducing the momentum for global warming: In irrigated rice cultivation, stopping the flooding of fields and reducing the amount of nitrogen fertilizer applied will diminish the net emission of greenhouse gases (GHGs) which are major contributors to global warming and thus to climate change (Chapter 11). Flooded rice fields are a major source of methane (CH_4) emissions, responsible for about 20% of agricultural releases of this gas into the atmosphere. Ceasing continuous flooding of rice paddies reduces methane emissions substantially.

It may be anticipated that stopping the flooding of rice paddies will, however, increase the production of nitrous oxide (N_2O), a more potent greenhouse gas that is produced under aerobic soil conditions. But evaluations in several countries have shown that with SRI methods, N_2O emissions do not increase by much, not enough to offset the benefits from reducing methane production.

When SRI methods are used in irrigated rice cultivation, net total GHG emissions from rice paddies are generally diminished by about 20 to 30% in terms of their global warming potential.[18] SRI methods also reduce the ancillary production of carbon dioxide (CO_2) associated with rice cultivation, but this is hard to measure comprehensively. SRI's soil management, by growing larger roots, also contributes to the sequestration of carbon in the soil, which helps to reduce atmospheric CO_2 levels.

Gender equity: Most of the labor for growing the world's rice supply is provided by women, whose work in growing rice is arduous and often debilitating, with adverse effects on their health and quality of life. SRI practices avoid the transplanting and weeding of rice by hand in standing water and introduce simple mechanical hand implements. These practices provide health improvements for women as well as other benefits (Chapter 14). Women gain from SRI's usually reducing the labor requirements for growing rice, and from having a more assured food supply for their families, with some of their time freed up for other activities.[19]

Food and nutritional benefits: In China, Cuba, India, Sri Lanka and Kenya, it has been found that when SRI paddy rice is milled to remove the husks and bran from around grains, 10% to 15% more polished rice results from each bag of harvested paddy rice. Why? Because SRI panicles (heads of rice) have fewer unfilled grains, so there is less chaff. Also fewer rice grains are broken during the milling process. Thus, the amount of edible food produced per hectare is 10-15% more than the amount reported for farmers' harvest from their fields.

Also, some recent studies have shown that the grains of rice grown with SRI practices have higher concentrations of micronutrients such as iron, zinc, copper and manganese.[20] Such agronomic biofortification of grain can help to combat micronutrient deficiencies, often referred to as 'hidden hunger' (Chapter 10). In addition, persons who eat SRI-grown rice often judge its taste and other eating qualities to be superior to those of conventionally-grown rice. However, such qualities are harder to measure and quantify than the other benefits noted above, and for most people they are a lesser consideration.

COSTS OF SRI

With so many benefits generated, there must also be some costs to consider. So far, the costs have proved to be surprisingly few. And some of the costs have compensating benefits, so that they are not unmitigated costs. For this reason, the barriers to adoption of SRI methods have usually been more mental than material. But there are costs that should be noted.

Learning costs: Whenever any innovation is introduced, there will always be some costs of time and usually money to acquire proficiency with and confidence in the new techniques. How great these costs will be will vary widely and will depend on how steep or flat are the learning curves involved.

There must, of course, be some expenditure for training, for demonstration plots, and for other methods and personnel used to communicate about the new ideas and opportunities. How much is expended will affect the speed and scale of uptake of SRI: the more resources invested, the greater and quicker will be the return. The returns from using SRI methods make expenditures on training and learning more of an investment than simply a cost because once the methods are learned, they can be used by farmers without additional cost for as long as they are beneficial.

Often, farmers who convert their fields from conventional farming methods to ‘organic’ methods of agriculture experience one or more seasons of lower yield while their soil systems adjust to and recover from prior fertilizer-dependent cultivation. However, SRI farmers usually find that the new methods give them higher yield from their first season. Even so, farmers who take up SRI need to be prepared to invest some time and other resources for making the conversion.

Increased labor, at least initially while learning: SRI requires that the planting and managing be done more carefully than previously, providing the plants with timely but sparing applications of water, making compost from available biomass to replace (as much as possible) synthetic fertilizer, and controlling weed growth with mechanical weeding when rice paddies are not kept flooded. These operations will take more time and effort at first. But once learned they can take less time, and there are compensating reductions in cost as noted above.

Early on, SRI was labeled as too labor-intensive for easy or widespread adoption.[21] This characterization discouraged many farmers and researchers from taking SRI seriously and from evaluating it for themselves. Since SRI requires relatively more labor than capital, it is ‘labor-intensive’ by definition. However, the critical consideration for farmers is whether or not SRI requires more labor than they are currently expending to grow their rice. Whether or not SRI requires farmers to invest more labor will depend upon how labor-intensive are their present practices that SRI would replace.

As discussed in Chapter 7, throughout most of Asia, where 90% of the world's rice is produced and consumed, rice cultivation is currently relatively labor-intensive. As seen from early evaluations of SRI in Asian countries, once its methods have been learned, SRI has proved to be labor-saving, or at least labor-neutral. When learning any new technique, some time will be required to master it. So how much more (if any more) labor is required for SRI is thus a highly contingent question. Certainly SRI will require more time and effort at first, but this should be a transitory cost.

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*In **Kenya**, a study of 40 farmers in their first year of SRI use in that country's largest irrigation scheme, Mwea, found that farmers' labor inputs per hectare were 9% higher on average. However, in one-third of the units studied, farmers' labor inputs declined by 13%. So, SRI can be labor-saving for Kenyan farmers even at the outset depending on their prior levels of labor input and on their adeptness in learning. Under SRI management, average yield increased by 33% for all of the farmers who used SRI methods, with water savings of 28% and a seed saving of 87%.*[22]

*In **India**, researchers evaluating rice cultivation in the state of Andhra Pradesh compared SRI with farmers' prevailing current methods of rice production. The only negative effect from SRI adoption that the researchers found was a 50% reduction in farmers' need to hire agricultural labor because household labor was sufficient to handle most SRI operations.*

Retrenchment in the amount of wages that SRI farmers paid to laborers, most of them women, was considered as a significant social cost, as their families were usually landless and dependent on this income. However, if farmers actually need less total labor as a result of their adopting SRI, this means that SRI methodology is not really intrinsically more labor-intensive. This finding contradicted the widespread negative stereotype of SRI.

If adopting SRI methods reduces employment opportunities for some laborers, this presents a social issue that should be addressed. The Andhra Pradesh research documented significant economic and environmental benefits that would be forgone by farmers and by India if SRI methods were not taken up. Comparisons between SRI and conventional farming found that SRI gave 60% higher crop yield per hectare, while net greenhouse gas emissions per hectare were lowered by 40%. Farmers' requirements for groundwater and for fossil fuel were lowered on SRI plots by 60% and 74%, respectively.

With lower costs and higher yield, farmers' net economic returns were found to increase more than four-fold with SRI.[23] *The researchers' calculations showed how adopting SRI methods generated economic gains much greater than laborers' losses. Compensating the latter by private or public transfers would be positive-sum, making SRI's benefits more equitable as well as attractive.*

Need for water control: Managing water more carefully entails some greater cost of labor and time, and possibly some investment in physical infrastructure where current facilities do not enable farmers to apply smaller amounts of water to their fields on a reliable basis. Possibly there needs to be social infrastructure such as water user associations to manage a smaller supply of irrigation water more precisely and reliably.

As water for agriculture becomes scarcer and less reliable, water will become more valuable in economic terms. This means that making investments in infrastructure for water saving will become more and more profitable and economically justifiable. Indeed, they will become more necessary in water-constrained areas if rice production is to be continued.

Saving water is becoming an ever-greater benefit for farmers and for society because water use in agriculture has large opportunity costs in terms of both industrial, domestic and other uses. In many areas, long-standing traditions of free and unlimited supplies of water for crop production are under stress and cannot be sustained. Thus, making investments of both labor effort and capital to be able to apply water more sparingly and in a controlled manner is becoming more of a benefit than a cost, with higher economic rates of return.

Soil fertility?: Another concern or caution sometimes expressed about SRI has been that its higher yields will lead to the depletion of soil nutrients when synthetic fertilizers are not used to augment or restore the soil's nutrient supply. Depletion of specific nutrients is always possible, of course, and if this becomes a problem, soil-nutrient amendments can be made since SRI practices do not need be fully 'organic.' As a rule, however, SRI farmers have found that as long as they provide their fields and crops with sufficient organic matter (manure, compost, mulch, or crop residues), yields are more likely to increase from year to year than to decline, with a build-up of nutrients in the soil rather than a depletion.

SRI experience calls into question some of the current scientific thinking about soil fertility and management, as seen in the box below. SRI learning and evidence cast an optimistic light on food production possibilities in the decades ahead, so long as adequate levels of soil organic matter can be maintained. Enhancing soil organic matter has the added benefit of increasing carbon sequestration which will buffer the dynamics that are contributing to global warming.

Preserving soil fertility certainly does entail some costs, particularly of labor, to maintain a sufficient supply of organic matter in the soil. But the benefits of such management should outweigh the costs, especially if the services of beneficial soil organisms which live around, on and inside plants are mobilized, stimulated by the increases in soil organic matter. SRI experience and research both support what could be called the 're-biologization' of agriculture.[24]

As discussed in Chapter 3, the productive benefits of SRI crop management were first evaluated systematically in Madagascar in a conservation-and-development project in the zone around Ranomafana National Park, starting in 1994. The project was intended to give very poor, smallholding farmers who lived around the Park's large rainforest some attractive alternatives to their slash-and burn cultivation which was encroaching on and destroying the region's prolific but endangered biodiversity.

According to the criteria of accepted soil science, the soils around Ranomafana Park were incredibly poor, highly acidic, with low to very-low nutrient availability in all horizons. Most crucial, they were very deficient in available phosphorus. Tests showed that the soils around Ranomafana had less than half the minimum level of available phosphorus that agronomists considered necessary to get an acceptable crop yield.[25]

Yet farmers around Ranomafana using SRI methods were able to raise their average yields from 2 tonnes per hectare to 8 tonnes, a four-fold increase, planting their same varieties (mostly traditional) on the same poor soils, using less water and less seed, and applying composted vegetative material rather than chemical fertilizer.[26]

This huge yield increase, achieved without 'improved' varieties and without applying large amounts of fertilizer, was initially dismissed by most soil scientists as impossible on such poor soils. However, it sparked considerable interest and curiosity beyond Ranomafana, giving impetus to the story that follows. Something was happening that diverged greatly from the accepted predictions of crop and soil science.

Below is shown a field of SRI-grown rice in Madagascar whose yield was calculated by a government technician to be 17 tonnes per hectare. If the yield was even half this much, that would still be four times the country's average paddy rice yield. This was achieved with a traditional, 'unimproved' variety of rice, not a new, 'improved' one. Note how even with huge panicles of grain hanging down from tillers that are as tall as the farmers, the plants remained upright, not falling over and lodging.

More can and will be said about the pluses and minuses of using SRI methods under a variety of circumstances. From the above summary of benefits and costs, readers should have a good idea of what this innovation can offer to farmers and their families, and also benefiting consumers, as well as maintaining the quality and sustainability of natural environments. It suggests why knowing how this innovation arose, how it gained acceptance, and how it has spread around the world despite some resistance, should be both interesting and worth knowing.

It is hard to imagine many innovations that are better designed and better positioned to address some of the most serious problems that we have to deal with in this 21st century, when economic, social and environmental sustainability are all at risk. Effective responses to these challenges will need to come jointly from the biological sciences and the social sciences, both of which are woven into the SRI story.

NOTES AND REFERENCES

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[3] P.L. Pingali, M. Hossain and R.V. Gerpacio, *Asian Rice Bowls: The Returning Crisis?* International Rice Research Institute, Los Baños, Philippines (1997); M.S. Swaminathan, 'Can science and technology feed the world in 2025?' *Field Crops Research*, 104: 3-9 (2007); H.C.J. Godfray, J.R. Beddington, I.R. Crute, L. Haddad, D. Lawrence, F.J. Muir, J. Pretty, S. Robinson and C. Toulmin, 'Food security: The challenge of feeding 9 billion people,' *Science*, 327: 812-818 (2010); D.K. Ray, N.D. Mueller, P.D. West and J.A. Foley, 'Yield trends insufficient to double global crop production by 2050,' *PLoS ONE*, 8(6) (2013). The narrative of the Green Revolution as necessary and a huge success has been challenged by some historians. See Glenn Davis Stone, 'Commentary: New histories of the Green Revolution,' *The Geographical Journal*, The Royal Geographical Society, London (2019). https://rgs-ibg.onlinelibrary.wiley.com/doi/pdf/10.1111/geoj.12297

[4] Farmers' view that rice fields should be kept flooded if possible was ratified by scientific opinion. In his book widely regarded as a bible for rice agronomy, a senior scientist at the International Rice Research Institute, S.K. DeDatta, wrote "rice thrives on land that is water saturated, or even submerged during part of all of its growth cycle … most rice varieties maintain better growth and produce higher grain yields when grown in flooded soil than when grown in non-flooded soil" (pages 43, 297-298). *Principles and Practices of Rice Production*, J.W. Wiley, New York (1981). This understanding of how best to grow rice has been shown by SRI experience and by research to be simply and completely wrong.

[5] B. Abraham et al., 'The System of Crop Intensification (SCI): Reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops,' *Agriculture and Food Security*, 3:4 (2014); P. Adhikari et al., 'System of Crop Intensification for more productive, resource-conserving, climate-resilient and sustainable agriculture: Experience with diverse crops in varying agroecologies,' *International Journal of Agricultural Sustainability,* 15: 1-28 (2017).

[6] A third reason for better performance of SRI-grown rice plants is that the practices create a less dense canopy above-ground, with more air circulation and less humidity. Such a micro-environment is less favorable for pests and disease, and more facilitative of photosynthesis. This kind of micro-environment results from the various SRI practices that promote greater root growth and health and that are conducive to more biodiversity in the soil. We focus on root systems and the life in the soil as these are largely ignored by

conventional practice, and there is now much research documenting their positive effects. However, improving the above-ground environment for rice crop growth is also an essential part of the synergistic effects that result from SRI management methods.

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[8] C. Gorman, 'Exploring the human microbiome' [Interactive], *Scientific American*, May 15 (2012). The plant microbiome is discussed in Chapter 5.

[9] D. Montgomery and A. Biklé, *The Hidden Half of Nature: The Microbial Roots of Life and Health*, W.W. Norton, New York (2016).

[10] Because in an era of Photoshop there might be doubts about a picture like this, the next season Dr. Rena Perez who had taught SRI methods to Luis Romero visited his farm each week and videoed the observable changes in plant growth throughout the cropping season. This visual record can be seen at: http://sri.cals.cornell.edu/countries/cuba/SICAenglish.wmv

[11] Countries are listed with extensive supporting documentation on each on the SRI-Rice website at http://sri.cals.cornell.edu/countries/index.html

[12] K. Palanisami, K.R. Karunakaran, U. Amarasinghe and C.R. Ranganathan, 'Doing different things or doing it differently? Rice intensification practices in 13 states of India,' *Economic and Political Weekly,* 48: 51-58 (2013).

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[14] P. Jagannath, H. Pullabothla and N. Uphoff, 'Meta-analysis evaluating water use, water saving, and water productivity in irrigated production of rice with SRI vs. standard management methods,' *Taiwan Water Conservancy*, 61: 14-49 (2013).

[15] A.K. Thakur and N. Uphoff, 'How the System of Rice Intensification can contribute to climate-smart agriculture,' *Agronomy Journal*, 109: 1163-1182 (2017).

[16] In the same year, a research team of the International Water Management Institute based in Sri Lanka evaluated the results of 60 farmers using SRI methods in two districts, matched with 60 farmers employing their usual methods. In a season that had 75 days of drought, the SRI rice plants had an 80% survival rate of panicle-bearing tillers vs. 70% with conventional practices, and 25% higher seed weight. Although the seeding (kg per ha) in SRI fields was 85% lower, with the number of plants similarly reduced, the grain yield from SRI fields was 33% higher. R. Namara, D. Bossio, P. Weligamage and I.

Herath, 'The practice and effects of the System of Rice Intensification (SRI) in Sri Lanka,' *Quarterly Journal of International Agriculture*, 47: 5-23 (2008).

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[18] N. Uphoff, *The System of Rice Intensification (SRI): Responses to Frequently-Asked Questions*, FAQs 4 & 4.1 (2015); and A. Gathorne-Hardy, D. Narasimha Reddy, M. Venkatanarayana and B. Harriss-White, 'A Life Cycle Assessment (LCA) of greenhouse gas emissions from SRI and flooded rice production SE India,' *Taiwan Water Conservancy*, 61: 110-125 (2013).

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