UNDERSTANDING THE SYSTEM OF RICE INTENSIFICATION:
A CASE STUDY FROM LIBERIA

A Thesis

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ABSTRACT

The System of Rice Intensification (SRI) was introduced to Liberia in 2012. Since then, it has been widely promoted across the country to enhance rice productivity. This ecological methodology has proven a viable alternative to conventional and traditional rice cultivation elsewhere in the world, particularly among smallholder farmers, as the low-input, high-output production system increases food security and income while conserving natural resources and relying less on agrochemicals. There is a growing body of literature dedicated to SRI, but little is known about farmer experience with this production system in Liberia. This paper explores farmer perceptions using qualitative research methods and examines the challenges and opportunities for scaling up SRI in the Liberian context. Results from this research indicate substantial benefits for farmers, as yield increases were reported unanimously. However, low and partial comprehension of SRI principles and practices, along with infrastructural barriers, limited the persistent adoption.

BIOGRAPHICAL SKETCH

Garrett Quade was born and raised in the San Joaquin Valley of Central California. His childhood upbringing in a small, rural community provided an early education on the interconnected nature of food, people, and the environment, which continues to motivate his academic and professional aspirations. Currently, Garrett is a graduate student in the Department of Global Development at Cornell University, studying international agriculture and rural development, with ambitions of fighting hunger, poverty, and climate change through agricultural interventions. His interests lie at the intersection of agroecology, economic empowerment, food security, and natural resource conservation, and he is particularly intrigued by the prospect of combining policy with practice to advance innovative ideas for supporting smallholder farmers in sub-Saharan Africa.

Garrett graduated with a bachelor of science in agricultural business from California State University, Fresno in 2012. During his undergraduate career, he had the fortunate opportunity of traveling to China with the Department of Agricultural Business, which afforded him a first-hand look at the global food system and profoundly impacted his understanding of international affairs. Prior to his studies at Cornell, Garrett served as a U.S. Peace Corps volunteer in the Oromia region of Ethiopia, where he worked with smallholders farmers and youth groups to implement nutrition-sensitive agriculture projects. Moreover, he holds years of applied knowledge in crop production, specifically, with irrigation and fertility management and experience in agricultural commodities marketing on domestic and international levels. This multidisciplinary background has equipped Garrett with a comprehensive set of skills which enable him to critically engage in development initiatives and collaborate with others through a spirit of participatory learning and co-creation.

To the smallholder farmers,

who toil in the fields to feed their families,

and whose work is often underappreciated,

this paper is dedicated to you.

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Lastly, I wish to express thanks with the utmost gratitude to the farmers who participated in this research. Your resolve and dedication to farming and family are the backbone of society, and my intentions in this study are to share your voices with others to effect change for individuals, communities, and the nation of Liberia. Through collective action rice self-sufficiency is possible and your contributions to this research revealed that. It was my privilege to be welcomed into your communities and learn from your experiences. From the bottom of my heart, thank you.

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INTRODUCTION

The global population will surpass 8 billion people by the end of this year (UN DESA, 2022), and with unprecedented catastrophes recurring around the world due to climate change, increasing food production is imperative for meeting the demands of all people and ensuring political stability. At present, however, the global food and agriculture system is a leading contributor to greenhouse gas emissions, natural resources exploitation, social marginalization, and civil unrests. Without major systemic change, the drive to produce more food for a growing population will bring further damage to the already compromised and fragile natural systems in which all life depends on.

To overcome the looming threats of chronic food insecurity and calamity, food system actors and governments alike must prioritize more efficient, equitable, and ecological methods to sustainably intensify agricultural production and eliminate its harmful externalities. Shifting the paradigm from *business-as-usual* to a system that recognizes the urgent need for environmental conservation, and therefore incentivizes land stewardship, will require action from individuals, institutions, and the international community writ large. So far, efforts to secure commitments and collaboration among global stakeholders have proved painstakingly slow. While such efforts are critical, there is growing evidence that certain changes in agricultural practices can help advance global environmental sustainability and climate change mitigation goals while bringing benefits to the farmers who adopt them. Thus, improving soil health, protecting and conserving fresh water, safeguarding biodiversity and natural resources, and refocusing the attention on how and where food is grown should define the global agenda for agriculture in the 21st century. A vital early step in this process is to identify *game-changing* innovations that already exist, increase understanding of their potential for adoption and adaptation across diverse agro-ecosystems at scale, and evaluate the benefits they provide – and to whom.

This paper examines the System of Rice Intensification (SRI) – an innovative approach to farming one of the most essential and widely cultivated food crops in the world. Originally developed in the 1980s under drought conditions in Madagascar (Stoop et al., 2002), this method has gained traction in many rice-producing countries over the years by increasing yields while using fewer inputs such as land, seed, water, and agrochemicals (Styger et al., 2011). SRI is a cost-effective production system, especially for small and limited resource farmers, and enhances the resilience of rice plants in the face of extreme weather events through a combination of ecological principles and agronomic practices (Thakur & Uphoff, 2017). In addition to greater capital and resource productivity, SRI facilitates farmer adaptation across a spectrum of landscapes (Uphoff et al., 2011) and reduces net greenhouse gas emissions per area cultivated (Kassam et al., 2011). For these reasons, SRI has been termed *climate-smart agriculture* by the Food and Agriculture Organization of the United Nations (FAO), the World Bank, Oxfam, and others alike (Barrett et al., 2021), and is currently being integrated into various commitments and nationally determined contributions to mitigate the climate crisis.

The SRI methodology offers benefits that can improve livelihoods for individuals and households in rural communities, as well as urban societies and ecosystems. An extensive literature cites poverty reduction, improved food security, increased off-farm employment, a greater sense of empowerment and agency among small, marginalized farmers, and conservation of natural resources as among the most notable benefits claimed by SRI advocates and practicing farmers. In addition, some governmental bodies have promoted SRI as a strategy for advancing national and state economic development agendas. Despite rising in prominence over the decades, the benefits of SRI have yet to be fully realized, and to achieve the optimum potential, an enabling environment consisting of infrastructure and policy is necessary to scale up implementation.

The proceedings in this paper explore the prospects of creating such an environment in the West African country of Liberia. The subsequent chapters detail extensive research on the subject and synthesize this information into three distinct sections. *Part I* comprises a volume of literature pertaining to rice cultivation, highlighting the differences between conventional rice production and the SRI methodology and laying the foundation for which this paper will build on. *Part II* encompasses the primary research that was conducted with farmers in Liberia, demonstrating the significance of this research and discussing the study design and key findings. Finally, *Part III* offers a suite of recommendations for policy makers and development practitioners based on the results of this study, and emphasizes mechanisms that can improve rice productivity in Liberia and contribute to agriculture-led economic development.

Qualitative research methods were used in this investigation which seeks to answer three exploratory questions: (1) How do farmers understand the SRI method? (2) Why do farmers adopt the SRI method? And, (3) what types of support are most valued by farmers? Data were collected through semi-structured interviews and focus group discussions in Liberia that covered a range of questions with regard to SRI and rice farming in the country, more broadly. Triangulation analysis was done using questionnaire responses, participant comments, and observations which aided in the examination of farmer perceptions and attitudes toward SRI. The main objective of this study was to gain a better understanding of farmer experience with this production system to assess the benefits it provides and identify potential barriers that limit farmer uptake in the country. The goal of this paper is to amplify the voices of farmers to inform the decision-making process and address poverty and food insecurity in Liberia through a holistic approach, one that fosters equitable and sustainable outcomes for society and the environment.

PART I – LITERATURE REVIEW

CHAPTER 1: RICE CULTIVATION

1.1 History at a Glance

Over the last 10,000 years agriculture has facilitated the establishment of civilizations around the world (Montgomery, 2007). Early domestication of plants and animals led to organized production of food, feed, fiber, fuel, and fertilizer, which transformed hunter-gathers into stationary farmers and stimulated the rapid increase in human population (Fuller & Stevens, 2019). Agriculture is the greatest factor to have contributed to mankind's exponential growth, and it continues to support the vast majority of livelihoods in developing countries (Castaneda et al., 2016). While hundreds of crops are now cultivated on a regular basis, three remain critically important to global food security: (1) maize, (2) rice, and (3) wheat. These three cereal grains have been grown for millennia and currently supply more than 40% of the world's daily caloric intake (FAO, 2018). Cereals are a foundational element in modern-day agriculture and consumption, due to their adaptive capacity in production, long-term storage life, versatility in food preparation, and dense concentrations of carbohydrates and other essential nutrients.

Rice is arguably the most cherished of the *big three cereals*, as it is cultivated in over 100 countries and a favorite among farmers in Asia and Africa (Laborte et al., 2017). The grain is a staple food for nearly half the world, with more than 3.5 billion people consuming it daily (Kritee et al., 2018; USDA-ERS, 2022). Its popularity stems largely from two plant species that evolved independently from one another with the help of environmental factors and human ingenuity in different parts of the world. *Oryza sativa* – the most commonly known rice species – is believed to have been domesticated along the lower Yangtze River basin in China between 8,000 and 9,000 years ago (Nakamura, 2010; Callaway, 2014), and has served as a fixture in the diet, culture, and trade of the country ever since. Whereas, *Oryza glaberrima* – the lesser-known rice species – was reportedly domesticated in the upper Niger River of West Africa around 3,000 years ago (Linares, 2002), and has supported diverse populations spanning from the Atlantic Coast of Senegal all the way to Lake Chad in the interior of the continent (Nayar, 2010). To date, only two rice species have been domesticated throughout the world, and while their origin stories vary by thousands of miles and more than 5,000 years, the practices of early cultivation are strikingly similar and, in many ways, influence how rice is produced in modern agriculture.

1.2 Conventional Practices and Current Challenges

Throughout this text, the term 'conventional' is used generally to define the most common cultivation practices in modern-day rice production. These practices include: continuously flooded irrigation, high plant density cultivation, and the use of agrochemical inputs for pest and fertility management. While numerous production systems with various practices encompass modern rice cultivation throughout the world, *conventional* will be used hereafter in this paper to reference these practices.

1.2.1 Water and Irrigation

The most distinguishing feature of rice production is the large volume of water it demands in comparison to other crops. Though cultivation is no longer confined to lands adjacent to surface water sources, rice farmers now rely on extensive networks of canals and hydrological situations to supply their fields with vast quantities of water to mimic the flooded environment in which the crop evolved (Bouman et al., 2007; Nakamura, 2010). Lowland cultivation makes up nearly 90% of modern-day rice-producing areas with both irrigated and rainfed production systems designed to submerge plants in water throughout the growing season (Bouman et al., 2007). This age-old practice is inspired by the notion that rice is an aquatic plant that requires saturated conditions to thrive (Uphoff, 2003), and continuous flooding provides additional benefits to farmers by limiting weed pressure and thus reducing labor requirements (Ismail et al., 2012). However, contrary to popular belief, studies have found while rice plants are flood-tolerant, the crop actually performs better and yields more grain with intermittent water applications (Ishfaq et al., 2020).

In recent decades, water-use efficiency in rice production has been a topic of increasing debate due to competing interests for water around the world and worsening water scarcity (UN-Water, 2021). Additionally, this conversation is gaining more political attention in light of the fact worldwide rice cultivation generates roughly *500 million tons* of carbon dioxide equivalent (CO_2e) emissions per year (Adhya et al., 2014). Methane (CH_4) – a potent greenhouse gas that is more than 25 times the global warming potential of CO_2 – is produced in substantial quantities under the anaerobic conditions of continuously flooded rice fields (Reddy et al., 2013). Current estimates suggest that rice alone accounts for *one-half* of all crop-related greenhouse gas emissions, and rice cultivation is responsible for approximately 2.5% of the overall anthropogenic warming effects (Kritee et al., 2018). Implementing water-saving techniques in rice cultivation could therefore yield benefits in the short-and long-term by: conserving essential water resources, increasing rice productivity, and mitigating the impact on climate change (Thakur & Uphoff, 2017).

1.2.2 Seeding and Transplanting

The majority of rice producers worldwide are smallholder farmers (Chivenge et al., 2021), and these farmers traditionally use one of two methods for planting rice fields: broadcasting seed over cultivable land, or transplanting clumps of seedlings randomly, or in a narrow line, throughout the field (FAO, 2016). In many rice-producing countries, rice is grown primarily for subsistence purposes and farmers routinely use high rates of seed (60 to 80 kilograms per hectare) for sowing and transplanting under the impression that more seed will return a greater yield at the end of the season (IRRI, 2022a). This grave misconception drives intense competition between rice plants for elements such as soil nutrients, solar radiation, and space to grow, and inhibits the crop's ability to fully develop and produce grain (Thakur & Uphoff, 2017). In addition, densely planted fields are more challenging for farmers to manage and create ideal circumstances for pests and diseases to wreak havoc. Paradoxically, heavy applications of seed in rice cultivation reduces the soil, plant, and labor productivity, lowering overall production, and driving some farmers to rely on chemical fertilizers for supplementing nutrients and pesticides for controlling pest populations. However, agrochemical inputs increase the operational costs for rice farmers and can result in unintended consequences (Pingali, 2012).

1.2.3 Nitrogen Fertilizer

Nitrogen (N) is the most common yield-limiting nutrient in rice production (Jiang et al., 2004), prompting farmers to apply it in the form of chemical fertilizers such as Ammonium Sulfate, Urea, or Diammonium Phosphate (IRRI, 2022b). These fertilizers are water soluble, highly mobile, and routinely over-applied to guarantee N is abundantly available for crop uptake (Chivenge et al., 2021). The excessive use of N fertilizer in rice cultivation creates substantial environmental risks due to temporary or permanent losses from denitrification, volatilization, immobilization, and leaching of N out of the root zone (Johnson et al., 2005). Globally, nitrogen-use efficiency in agriculture is astoundingly low at 47%, meaning less than half of the 115 million tons of N applied every year is effectively utilized, while the remaining 53% is destined to become an environmental pollutant (Lassaletta et al., 2014). Consequently, agricultural soil management is the largest source of anthropogenic nitrous oxide (N_2O) emissions (Del Grosso et al., 2022), posing unimaginable threats to humanity as this long-lived greenhouse gas is *more than 300 times* the global warming potential of CO_2 over 100 years (Tian et al., 2020). Rice cultivation is the third largest consumer of chemical fertilizer in the world, accounting for 16% of all N applications, and with a dismal nitrogen-use efficiency well below the global average for agricultural production, rice production is a leading contributor to N_2O emissions (Chivenge et al., 2021). Moreover, the lack of precision in N fertilizer applications combined with flooded irrigation practices in conventional production can pollute water sources through chemical runoff and leaching (Tayefeh et al., 2018). High concentrations of N originating from rice fields regularly contaminate water bodies and contribute to eutrophication (Leon & Kohyama, 2017) – a phenomenon currently endangering terrestrial and aquatic life and diminishing global fish stocks by decreasing oxygen in the water (US EPA, 2013). Furthermore, the careless use of N fertilizer deteriorates the physical, chemical, and biological properties of agricultural soils, causing rice yields to decline over time through nutrient toxicity and soil acidification (Srivastava et al., 2020).

1.2.4 Land-Use Change

With low crop productivity caused by high plant density and soil degradation stemming from mismanaged water and fertilizer applications, a significant concern regarding conventional rice cultivation is the conversion of land into agriculture, particularly in ecologically-sensitive areas. Farmers growing rice year after year without appropriately rotating it with other crops can mine essential plant nutrients from the soil, depleting soil fertility and rendering land unproductive over time. Many smallholders in Asia and Africa struggle to earn a living from farming and most cannot afford to address their declining crop yields by purchasing expensive chemical fertilizers. Instead, a cheaper alternative is to clear new land for crop production and shift cultivation every few years (Kamara et al., 2016). The so-called 'slash-and-burn' agricultural system has been common in the tropics for centuries, but with growing populations extending into new territories and the ever-increasing demand for food production, this practice is accelerating deforestation beyond reforestation capabilities.

Prevalent where arable land is sparsely available, slash-and-burn removes forested areas in favor of agricultural production, which disrupts the ecological processes and functions that support a healthy environment. This practice not only destroys natural habitats and threatens the existence of biodiversity but it undermines the earth's ability to sequester carbon while producing substantial greenhouse gas emissions in the act of burning these carbon sinks. Studies have found significant associations between rising rates of deforestation with the prevalence of food insecurity (Kumeh et al., 2022), but the gains coming from this type of land-use change are often marginal at best and short-lived (Tata Ngome et al., 2019). Meanwhile, the effects of land degradation and loss of these natural resources are long-term and can result in irreversible outcomes that will inevitably impact species, ecosystems, and the sustainability of rice production.

1.3 The Path Ahead

Rice is without a doubt one of the most important crops to feed the rapidly growing human population, but the cultivation practices of yesterday surely cannot advance food security today without sacrificing the prospects of tomorrow. While the issues discussed in this chapter are by no means a complete list of concerns, nor do they fully summarize the magnitude of stress on earth and its diverse inhabitants by staying the course, they intend to paint a compelling portrait as to why a transformation in rice cultivation is necessary. Indeed, this cereal will play a crucial role in shaping the future of the world with an increasing number of people depending on rice each day for sustenance. However, conventional rice cultivation is pushing the planetary limits. At present, rice farming utilizes around one-tenth of the world's arable land, consumes roughly one-third of its irrigation water, and accounts for more than one-seventh of the chemical fertilizer applications (Kritee et al., 2018), all of which have profound impacts on soil degradation, natural resource depletion, and increasing global temperatures. Therefore, it is critical for researchers, rice farmers, development practitioners, policy makers, and industry leaders to come together and reexamine the objectives for rice production and explore new avenues for cultivation that work in harmony with natural systems to ensure long-term sustainability for future generations.

CHAPTER 2: THE SYSTEM OF RICE INTENSIFICATION

2.1 Technological Adoption in Agriculture

In his book, *Innovation: The Basis of Cultural Change*, H.G. Barnett defines innovation as "any thought, behavior, or thing that is new because it is qualitatively different from existing forms" (pg. 7), and notes that innovations can garner adoption within a society of origin and diffuse beyond their societal borders through various means (Barnett, 1953). Historically, agriculture research and development (R&D) has relied on Rogers' *Diffusion of Innovation Theory*, which emphasizes the relative advantage, compatibility, complexity, trialability, and observability of an innovation to influence technological adoption among farmers (Rogers, 2003). This has primarily been accomplished through public sector research and extension models such as the transfer-of-technology (TOT) and the training and visit (T&V) system (Stoop et al., 2002) – wherein trained scientists establish the research agenda, conduct experiments in controlled environments, and share their findings with extensionists, who are responsible for disseminating this information to farmers (Chambers & Jiggins, 1987). During the Green Revolution (1960s-1980s), this approach facilitated incredible economic advancements and brought great societal relief for many developing countries in Asia and Latin America, although, positive impacts were not ubiquitous, especially for those in Africa (Evenson & Gollin, 2003).

Following the Green Revolution, agriculture R&D shifted away from the public sector and substantially toward the private sector (Norton & Alwang, 2020), with the latter embracing the TOT and T&V models while focusing on plant breeding programs, agrochemical inputs, genetic engineering, and other technological innovations to advance agricultural production (Herring & Paarlberg, 2016). Though privatization of R&D led to improvements in crop outputs, the factor productivity in many places began to plateau or even decline as intensive monocropping exhausted agricultural soils and increased production inputs such as high-yielding seed varieties, water, and fertilizers were needed (Pingali & Heisey, 1999). Today, TOT and T&V remain fairly common in agricultural development initiatives throughout the world, but the hierarchal structure and linear flow of information in these models critically lacks farmer engagement, two-way communication, and opportunities for user feedback. The approaches disregard indigenous agricultural knowledge and capabilities and view farmers simply as the ‘patients’ of agricultural science with no room for participation in the innovation process, and very little consideration is given to their heterogeneity (Chambers & Jiggins, 1987). Consequently, the ‘prescriptions’ offered by scientists are ineffective in diverse and variable contexts and thus undesirable, particularly among smallholders, who cannot afford to gamble on the costly technologies being marketed (Stoop et al., 2002). This profit-driven and technological focus has marginalized smallholder farmers and hampered efforts to raise crop productivity in some of the most vulnerable places of the world. Furthermore, for those with the means to adopt new technologies many discover a worsening dependence on external inputs which can have increasing economic and environmental costs (Pingali, 2012).

2.2 Going Against the Grain

One innovation that has deviated from mainstream agriculture R&D is the System of Rice Intensification (SRI), which was developed over a 20 year-period of observation and participatory research in collaboration with rice farmers (Laulanı´e, 1993). Rather than a specific technology promoted to farmers for rigid adoption, SRI offers farmers a suite of ecological principles and recommended agronomic practices designed to raise rice productivity through a knowledge-based management approach (Barrett et al., 2021). This methodology was born out of necessity during the 1980s to address chronic food insecurity in the midst of prolonged drought in Madagascar (Stoop et al., 2002). Since then, it has effectively spread to more than 60 countries in Asia, Africa, and Latin America (SRI-Rice, 2018), benefitting an estimated 10 to 15 million farmers along the way (Styger & Traoré, 2018). This wide-ranging uptake of SRI demonstrates the method's relative advantages over conventional practices; compatibility with local and national interests; lack of complexity in learning; ease in trialing for farmers; and observable differences between existing practices. Moreover, the implementation of SRI across diverse agroecological zones showcases its adaptability and versatility (Uphoff, 2016).

Civil society organizations and the advancements in communication technologies, namely, radio, mobile phones, and high-speed internet, have played tremendous roles in the dissemination of SRI and the encouragement of farmers to become not just consumers of research but producers as well (Styger & Traoré, 2018). While this knowledge-based methodology demands an inquisitive mindset, regular observations, and keeping detailed records, the simple principles can inspire local problem-solving and ultimately better farm management (Stoop et al., 2002). Farmer-to-farmer extension and informal networks have also been instrumental in the rapid diffusion of SRI, as innovative farmers and early adopters have the ability to share their knowledge easily and freely with no special technology necessary to do so.

Contrary to the primary strategies of the Green Revolution that espoused new hybrid seed varieties and agrochemical applications as the major drivers to increasing production (Thakur & Uphoff, 2017), SRI seeks to maximize the potential of individual plants through a concept known as the genotype and biophysical environment (G x E) interaction (Stoop et al., 2002). Hence, this method can be implemented with any rice seed available to farmers, and it has proven successful in irrigated cultivation as well as rainfed upland and lowland systems (Styger & Jenkins, 2014; Uphoff, 2016). The unconventional and farmer-centered production system goes against the grain of mainstream agriculture R&D and aims to increase rice productivity through efficiently utilizing production factors such as water, seed, land, and labor (Zhao et al., 2009).

2.3 What Exactly is SRI?

SRI is a production system based on the alternative understanding of rice agroecology, and using synergistic principles and practices it promotes better management of soil, crop, nutrients, water, and pests (Kassam et al., 2011). According to Styger and Uphoff (2016), the core tenets of SRI include four principles:

(1) Encouraging early and healthy plant establishment

(2) Minimizing competition among plants

(3) Building fertile soils well-endowed in organic matter and beneficial soil biota

(4) Managing water carefully to avoid flooding and crop stress

These principles remain fixed wherever rice is being grown and serve as the fundamentals for all farmers to understand. The recommended SRI practices, on the other hand, are fluid, and provide farmers a plethora of options that align with the principles to identify best management strategies, according to the biophysical environment and individual capabilities.

For example, the majority of SRI farmers germinate rice seed in a garden-like nursery and transplant viable seedlings between 8 and 15 days old in a lightly irrigated field (Stoop et al., 2002). Others may choose to direct-seed their rice fields ahead of the rainy season after conducting seed viability testing (Styger & Jenkins, 2014). Both practices ascribe to the same principle of early and healthy plant establishment but depending on resource availability, local conditions, or personal preferences one may be more suitable than the other (Styger & Traoré, 2018). A second example could be given for wider plant spacing, a practice which follows the second principle of minimizing competition among plants. The general rule is to plant single seedlings in a square grid pattern using spacing of 25cm x 25cm (Laulanı´e, 1993; Stoop et al., 2002; Styger & Jenkins, 2014); however, as SRI spread to new environments with varying degrees of soil types and textures farmers adapted this practice by planting seedlings at different widths, some using 20cm x 20cm, 30cm x 30cm, 40cm x 40cm, even going as wide as 50cm x 50cm (Uphoff, 2003; Ceesay et al., 2006). One of the key motives of this production system is to empower rice farmers by equipping them with new, yet similar practices that will complement existing knowledge and inspire on-farm experimentation (Mishra et al., 2006).

These management adaptations demonstrate how farmers can – and do – contribute to agricultural science and innovation, and further illustrate why they should not be reduced simply to a homogenous group. It is imperative for agricultural researchers and practitioners to learn from the unique experience and insight individual farmers possess and avoid the *top-down* or *one-size fits all* approaches that are far too common in agriculture R&D. Instead, development professionals must prioritize participatory research methods and listen to farmers, examine issues together, foster collaboration in the innovation process, and develop appropriate strategies that address context-specific challenges. Styger and Jenkins (2014) have developed a conceptual framework for SRI implementation in West Africa (**FIGURE 1**), but this tool is applicable with a broader audience and can be used by farmers, researchers, and development practitioners anywhere to stimulate creativity and drive further innovations. The framework lists key recommended SRI practices under the respective principle each applies to, and while this provides a comprehensive set of practices, it should be noted this is by no means an exhaustive list.

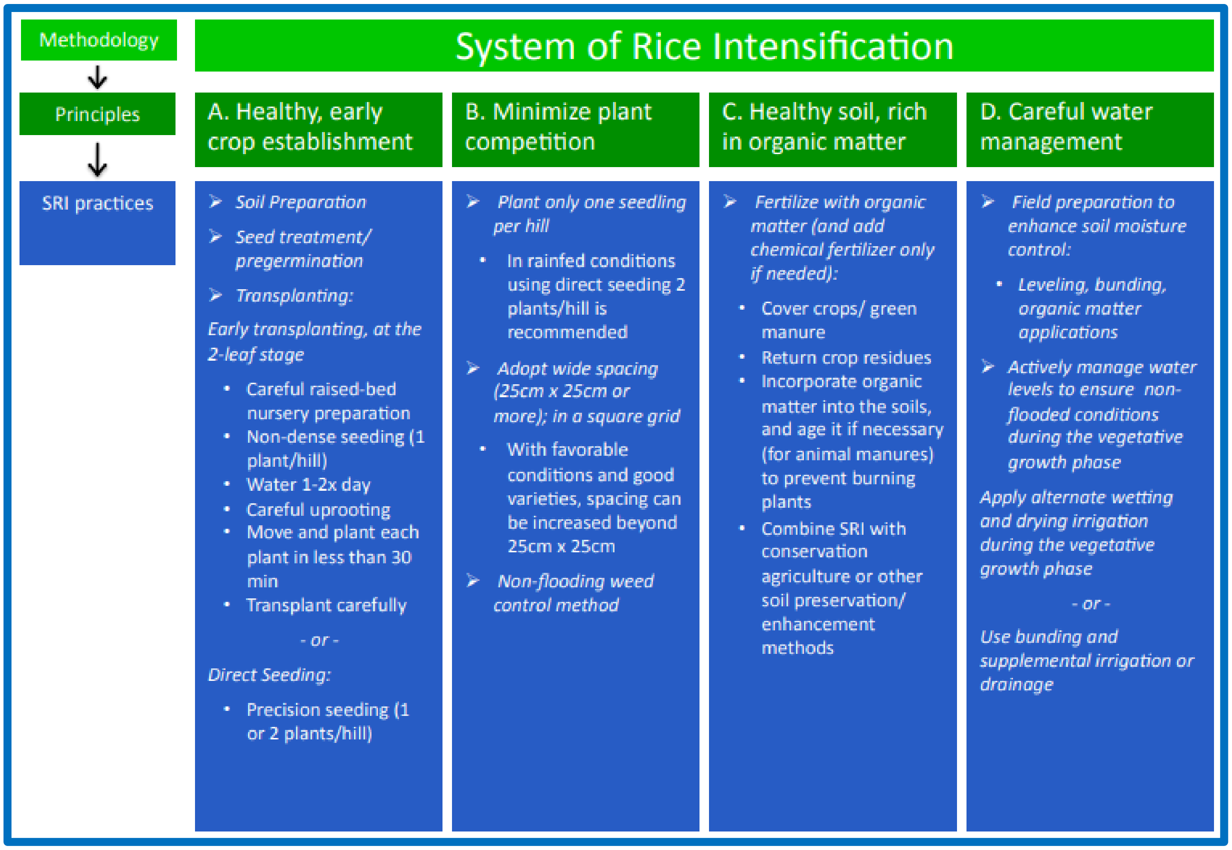

FIGURE 1: The SRI Conceptual Framework *(Styger & Jenkins, 2014)*

2.4 Soil Health and SRI Practices

Soil is the foundation for rice production. In fact, soil is the foundation for all terrestrial life, as it supports the ecological functions and processes that sustain healthy plant, animal, and human populations (Moebius-Clune et al., 2016). In rice cultivation, the physical and chemical properties of a soil are the primary concerns of most conventional farmers, and more specifically, the soil structure and availability of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) (Shrestha et al., 2020). These chemical elements are essential macronutrients for crop growth and development (IRRI, 2022c), but they can be scarcely available where rice production takes place year after year. Failure to rotate rice with other crops diminishes soil fertility over time, with N, P, K, and S being extracted each growing season in the form of plant residue and grain at harvest.

Additionally, some rice farmers purposefully degrade the physical structure of soil through tillage practices that create hardpan layers to prohibit water infiltration for enhanced puddling (Stoop et al., 2002). This effectively destroys soil aggregation, exposes precious organic matter to rapid decomposition and loss, and reduces soil nutrient availability and retention (Moebius-Clune et al., 2016). Consequently, many conventional rice farmers use chemical fertilizers to address their crop deficiencies. However, these inputs do not replenish soil nutrients rather than make them available to rice plants for a short period of time. Moreover, the excessive applications of ammonium-based fertilizers can pose significant soil management concerns by accumulating positively charged ions in the soil, causing elemental toxicity and soil acidification (Srivastava et al., 2020).

2.4.1 Natural Soil Amendments

One of the most significant factors differentiating SRI from conventional rice production is the emphasis this methodology places on building fertile soils that are well-endowed in organic matter and beneficial soil biota (*principle three*). The basis for this fundamental principle is in the recognition that organic matter plays an integral role in sustainable land management by mediating the interrelated processes of the chemical, biological, and physical properties of a soil. Although soil organic matter (SOM) makes up between roughly one and six percent of any given soil, even marginal losses caused by routine soil disturbance can disrupt the soil's ability to function properly (Magdoff & van Es, 2021). Enriching SOM is therefore important for long-term rice production and can be done in various ways, though ideally with the incorporation of locally available natural soil amendments such as plant residues, animal manures, or composts (Styger & Jenkins, 2014).

Unlike chemical fertilizers applied strictly to feed rice plants, natural amendments nourish both the soil and the crop by replenishing SOM which then serves as a source of carbon (C) and energy for numerous microbes, animals, and plants living in the soil (Thies & Grossman, 2006).

These organisms, also called soil biota, are a vital piece of the SRI puzzle as they convert organic forms of N, P, K, and S found in natural soil amendments into plant accessible nutrients (Thies & Grossman, 2006). Soil biota are not only important for effective nutrient cycling and soil fertility but they help suppress pests and pathogens as well, with a diversity of organisms in, on, and around rice plants having the ability to biologically regulate undesirable populations (Uphoff et al., 2006). Applying natural amendments stimulates the inner workings of this complex *soil food web* and reduces the need for purchasing agrochemical inputs (Magdoff & van Es, 2021). This creates twofold economic incentives for farmers by increasing crop yield and minimizing production costs for chemical fertilizers and pesticides, which can be expensive and difficult to source, particularly for smallholders who make up the bulk of rice producers worldwide (Tonini & Cabrera, 2011).

2.4.2 Early Transplanting

Along with enhanced chemical and biological properties, soil that is rich in organic matter possesses greater aggregate stability and water holding capacity (Moebius-Clune et al., 2016). These physical soil properties create a hospitable environment for rice plants, as a soil with good aggregation acts like a sponge to prolong the availability of water and nutrients for crop uptake (Magdoff & van Es, 2021). The SRI method exploits this relationship by establishing seedlings in the field at a young age (*principle one*), giving plants a boost for healthy growth and development in this nutrient-rich environment. Compared with conventional production, where seedlings are transplanted anywhere between 20 and 60 days old (FAO, 2016), SRI recommends transplanting rice at the two-leaf stage (8 to 15 days old) which maximizes nutrient absorption in the vegetative stage and encourages plants to grow a greater number of productive tillers (Uphoff, 2003). This extensive growth early in the season has various benefits for grain production and has also shown to be an effective strategy for competing with weeds, as rice plants under SRI successfully shade out weeds faster than those in conventional systems (Stoop et al., 2002). Moreover, researchers in Benin have found that early transplanting with SRI can shorten the crop cycle by up to two weeks (Gbenou et al., 2016), providing additional benefits to farmers for land preparation and cropping calendars. This practice can also mitigate the potential harm to overall plant health, as mature roots have yet to fully develop and therefore are less likely to get damaged during transplanting. This enhances the plant's ability to withstand biotic and abiotic stress throughout the growing season and reduces its vulnerability to climate shocks (Styger & Jenkins, 2014).

2.4.3 Wider Plant Spacing

Improving crop resilience and productivity are key motives under the SRI method, as well as increasing farmer income (Thakur & Uphoff, 2017). Each of the four SRI principles contribute to these outcomes in one way or another, but minimizing competition among plants (*principle two*) is uniquely suited to achieve them all. In conventional production, planting rice fields usually involves using clumps of 3 to 4 seedlings transplanted together in random fashion or in a narrow line 10cm to 20cm apart (Stoop et al., 2002; FAO, 2016), and in some instances, farmers heavily broadcast seed over the soil (Nayar, 2010; Styger & Traoré, 2018; IRRI, 2022a). Under the SRI method, the recommended practice is to transplant single seedlings per hole with 25cm between one another using a square grid pattern (Laulanı´e, 1993). This substantially reduces seed usage, cuts down production costs, and provides more space for mechanical weeding – a critical practice that will be discussed in greater detail later on in this chapter.

In a multi-year study conducted in the Timbuktu region of Mali, researchers found that SRI farmers could use as little as 6 kilograms of seed to plant one hectare of land – a reduction of 80 to 90% – and achieved higher incomes and yields per hectare as compared to traditonal practices (Styger et al., 2011). While fewer seedlings might seem counterintuitive to increasing production, reducing crop density limits competition between plants for soil nutrients, water, and light, which translates to healthier plant growth above and belowground with a greater number of tillers per square meter (Uphoff, 2003). Wider plant spacing also lowers the risk of pest and disease outbreak as more space among plants helps reduce the spread in the field, and because plants are healthier they are less susceptible to pathogens (Thakur & Uphoff, 2017).

FIGURE 2: Comparison of Rice Plants in Indonesia *(SRI-Rice, 2008)*

FIGURE 2 (above) showcases the difference in plant performance with wider spacing and SRI principles (SRI-Rice, 2008). The photo displays a farmer holding two rice plants, each grown from a single seed; in her right hand is a plant grown in high density conditions using conventional practices and in her left hand is a plant grown under the SRI method with wider spacing. This side-by-side comparison, although quite an extreme case, is an excellent example of the genotype and environment (G x E) interaction, and the potential rice plants are capable of producing if the right agronomic practices are applied.

2.4.4 Intermittent Irrigation

Rice plants have a unique ability to grow in a range of soils, climates, and hydrological situations (Bouman et al., 2007), and using ecological principles and agronomic practices, the SRI method aims to harness the genetic potential of the crop (Stoop et al., 2002). Managing water carefully (*principle four)* is perhaps the most challenging aspect of SRI as it requires a substantial effort in land leveling and field preparation for the uniform application of water. Though practices associated with this principle can vary based on capital and resources, the general recommendation is to keep soil moist by applying roughly 1cm to 2cm of water every week (Styger & Jenkins, 2014), opposed to the continuously flooded conditions found in conventional rice production. The synergistic SRI principles and practices are meant to yield multidimensional benefits, and as noted above, maintaining SOM improves soil aggregation and water holding capacity, which enhances the water-use efficiency with fewer and lighter irrigation applications.

The controlled irrigation practice known as *alternate wetting and drying* (AWD) is widely championed in conservation agriculture and is highly recommended for SRI farmers. AWD alone can reduce water use in rice fields by 25 to 70% without compromising yield (Ishfaq et al., 2020), and when combined with other SRI principles, increases in yield can be achieved (Ceesay et al., 2006). Intermittent irrigation practices allow the soil to remain damp, yet aerobic, which enables the flow of oxygen in the soil that is vital for root and shoot growth, particularly in the vegetative stage (Lampayan et al., 2015). The advantage of SRI and AWD can be seen in **FIGURE 3** (below), which exhibits the root systems of two rice during the vegetative stage (Thiyagarajan et al., 2009). The image was taken by researchers studying the effects of SRI at an agriculture experimental station in India. In this picture, healthy and vigorous roots developed under SRI are contrasted with the stunted roots suffering from necrosis due to hypoxic soil conditions found in continuously flooded cultivation. This comparison of root systems presents a persuasive case for the benefits of SRI in the vegetative stage – a critical time for enhancing root growth and productivity for overall plant performance and reproduction.

FIGURE 3: Comparison of Rice Plant Roots in India *(Thiyagarajan et al., 2009)*

2.4.5 Mechanical Weeding

Abiding by SRI principles enables rice farmers to increase crop performance; however, the same mechanisms that boost rice productivity have the unfortunate consequence of increasing the prevalence of undesired plants in the field. Similar to rice plants, grasses and weeds also benefit from nutrient-rich soil, more light interception, and intermittent irrigation practices. Although not a principle, per se, mechanical weeding is an SRI practice that is critically important. Regular weeding using a rotary weeder, hand hoe, or other mechanical implements can provide myriad benefits for SRI farmers as compared to hand weeding or conventional herbicides, primarily by incorporating organic biomass into the soil, helping stimulate biological activity and aerating the soil for healthier root growth and development (Veeraputhiran et al., 2014). The practice should begin around 10 to 14 days after transplanting (Styger & Jenkins, 2014) and usually occurs three to four times over the season (Stoop et al., 2002). While the start date and weeding frequency usually depends on the rate at which weeds emerge in the field, managing weeds early will help reduce competition with rice plants for nutrients, water, and light, and prohibit weed growth and the dispersal of new seeds.

Weeds pose a larger problem for SRI farmers than for conventional rice farmers, given the non-flooded conditions, and often increase labor requirements for farmers throughout the season. Nevertheless, using a mechanical weeder can turn this additional labor cost into a benefit, as an increase in yield is experienced with each mechanical weeding session (Thakur & Uphoff, 2017). Researchers from Tamil Nadu Agricultural University in India quantified the impact of different weeding intervals on rice yield and income, examining the benefits of a rotary weeder for both SRI farmers and those using conventional best management practices in the Manimuthar sub basin of the Tamil Nadu State (Veeraputhiran et al., 2014). This study found that farmers practicing SRI not only outperformed conventional farmers in terms of yield per hectare, but they earned a higher net income as well; meanwhile, the yield and income margins grew significantly with each additional weeding session under SRI as compared with only marginal increases in conventional production (Veeraputhiran et al., 2014). **TABLE 1** (below) illustrates the results of this study in greater detail, presenting the yield, income, and benefit-cost ratio achieved under different weeding intervals for both SRI and conventional farmers. This research was conducted with farmers across

18 on-farm plots using a rotary weeder, and demonstrates the importance of mechanical weeding in rice cultivation and its association with soil aeration and yield increases.

TABLE 1: Weeding Intervals - Comparison of SRI and Conventional

Number of Rotary Weeding	**Grain Yield (ton/ha)**		**Net Income (x10^3/ha)**		**Benefit-Cost Ratio**	
	SRI	Conventional	SRI	Conventional	SRI	Conventional
Four Times	7.05	5.68	43.10	27.35	2.56	1.93
Three Times	6.39	5.53	37.39	26.92	2.32	1.93
Two Times	5.72	5.27	30.83	23.98	2.10	1.83
One Time	5.09	5.35	25.59	25.60	2.01	1.91
Total/Mean	6.06	5.46	34.23	25.96	2.25	1.90

(Transcribed by author from Veeraputhiran et al., 2014)

2.5 Implications for Further Research

Across the board SRI promotes better management of land, labor, crop, and capital; and through simple alterations to practices farmers can increase rice productivity and conserve vital natural resources (Kassam et al., 2011). This cost-effective production system offers life-changing possibilities for the 145 million households around the world that depend on rice cultivation for their primary livelihood (Kritee et al., 2018) with the methodology contributing to greater yield and income (Styger & Traoré, 2018). Moreover, transitioning away from conventional practices and toward SRI can substantially reduce the alarming greenhouse gas emissions associated with rice cultivation, namely, methane (produced under continuously flooded cultivation), nitrous oxide (generated from excessive fertilizers applications), and carbon dioxide (embedded in fuel usage and fertilizer manufacturing), thus providing a multitude of benefits to the planetary ecosystem in which all life on earth depends on (Thakur & Uphoff, 2017).

While SRI presents numerous advantages over conventional production, this methodology has not been immune to controversy, with criticisms coming from some scientists within the agricultural research community, including some affiliated with the International Rice Research

Institute (IRRI) and the International Fertilizer Association (IFA). Skeptics have dismissed the yield increases as advertised with SRI practices, alleging the results of research lacked empirical evidence and questioning the rigors of data collection (Dobermann, 2004; Sheehy et al., 2004). Some have cast SRI as a hoax, drawing the comparison to unidentified flying objects (UFOs) – only using the acronym for “unconfirmed field observations” – while simultaneously expressing their discontent over funding agencies supporting SRI initiatives opposed to “sound scientific approaches” (Sinclair, 2004). Other opponents have suggested endogenous factors contributed to the fantastic results in Madagascar and therefore these findings are not generalizable for other rice-producing countries, yet curiously as the same time claiming the system is nothing more than “best management practices” (McDonald et al., 2006). Though critiques of SRI have receded over the years with new studies coming from a variety of countries and landscapes (Uphoff et al., 2011), governments choosing to support SRI based on their own evaluations (Thakur & Uphoff, 2017), and even IRRI stamping its approval of SRI as a greenhouse gas mitigation strategy (IRRI, 2022d), some questions still remain.

The decreases in operating expenditures for inputs such as seed, water, and agrochemicals under SRI are well documented (see e.g., Stoop et al., 2002; Uphoff et al., 2003a; Zhao et al., 2009; Styger et al., 2011; Styger & Traoré, 2018), however, this production system is often viewed as labor-intensive for farmers, prompting some social scientists to wonder if SRI is in fact ‘pro-poor’ (Graf & Oya, 2021). Labor is often a resource-poor farmer’s best asset, but a significant increase in labor could force a shift in household labor allocation, and though higher incomes may be earned with the SRI method, this shift could negatively affect the overall household well-being (Takahashi & Barrett, 2014). Additionally, some studies have found that many farmers choose to discontinue the SRI method after a certain point, or selectively adopt certain practices due to labor constraints (see e.g., Moser & Barrett, 2003; Moser & Barrett, 2006; Arsil et al., 2019; Barrett et al., 2021). These socio-economic factors have excited considerable debate over the true benefits of this methodology as well as what practices exactly constitute SRI, given the number of options for farmers to choose from.

There is a growing body of literature dedicated to SRI. At present more than 1,400 journal articles have been archived in a searchable data base at Cornell University (SRI-Rice, 2022a). However, further context-specific studies are needed to better understand the socio-economic impacts of adoption. The next section of this paper aims to investigate some of these unanswered questions, more specifically, how farmers comprehend the SRI method, what factors motivate adoption of practices, and the types of support that are most valued by farmers who practice SRI. This methodology is rooted in farmer-centered participatory research, and with over 60 countries now implementing SRI, there are ample opportunities to learn from farmers who hold varying degrees of experience with this system. The study detailed in the following section explores how farmers in Liberia perceive the SRI method and what kind of benefits and barriers they experience while implementing the alternative practices in rice cultivation.

PART II – PRIMARY RESEARCH

CHAPTER 3: LIBERIA

3.1 Justification

The System of Rice Intensification (SRI) in Liberia presents an intriguing case study for a variety of reasons. First, rice plays an integral role in the Liberian society and economy as the staple food for millions. Second, the agroecological conditions in Liberia are exceptional for rice cultivation, yet the vast majority of rice consumed in the country is currently imported. Third, chronic poverty and food insecurity are major impediments to economic development and disproportionately burden those in rural communities and farming households. Finally, there is ongoing support for the SRI methodology among local and international organizations in Liberia, providing a unique opportunity to study how farmers perceive this production system and the impact it is having on livelihoods. As a cost-effective strategy to increase rice production through better management of resources and capital, SRI can help to address the multifaceted challenges that continue to stifle economic growth in the country. The extensive knowledge held by farmers, along with Liberia's abundant natural resources and demographic dividend posit great potential for scaling up this production system. In addition, the local and international organizations working to promote SRI in the country can provide valuable input to better understand what has and has not worked in capacity building and development projects.

3.2 Social, Economic, and Political Considerations

<u>*3.2.1 Demographic Dividend*</u>

Liberia is located on the Northern Atlantic Coast of Africa, situated between Sierra Leone, Guinea, and Cote D'Ivoire in a region historically known as the 'Rice Coast' (Nayar, 2010). The country is home to over five million people (World Bank, 2022) and is made up of 15 counties

(**FIGURE 4**). The annual population growth rate is 2.4% with the economically active population (EAP) – 15 to 64 years old – increasing each year (World Bank, 2022). More than half the country is considered part of the EAP and approximately 90% of Liberians are under the age of 35 (IFAD, 2019; World Bank, 2022). The capital city of Monrovia is located in Montserrado County and is by far the most populated area of the country, holding about one-third of Liberia's people (PAPD, 2018). Although an agrarian society, more than 50% of the population resides in urban areas (PAPD, 2018; World Bank, 2022). Urbanization has been steadily increasing since the 1980s, due primarily to underdeveloped infrastructure in rural areas and internal population displacement caused by decades-long civil conflicts (Peterson, 2016; World Bank, 2022). While an urbanizing population is an indicator of the structural transformation associated with economic development (Timmer & Akkus, 2008), low agricultural productivity indicates the traditional agricultural-led economic growth model does not apply (PAPD, 2018).

Liberia is currently among the least developed countries in the world, scoring 0.481 on the Human Development Index (HDI) and ranking 178th out of the 191 countries and territories that were surveyed (UNDP, 2022a). Specifically, the country lags behind in the access to knowledge and a decent standard of living. Multidimensional poverty afflicts more than half of the population while farming households and rural areas suffer at rates of more than 70% (LISGIS, 2017; PAPD, 2018; UNDP, 2022a). Ensuring education and employment opportunities are available for this young and rapidly growing population is critical to sustaining social cohesion and improving the economic standing of the country. Therefore, the current government has prioritized these issues under their *Pro-Poor Agenda for Prosperity and Development* (PAPD), a five-year, four-pillar development plan set for fiscal years 2018 through 2023 (PAPD, 2018). Raising the standard of living for all Liberians is imperative for the country, especially when considering the political, economic, and ethnic disparities that have fueled conflict in the past.

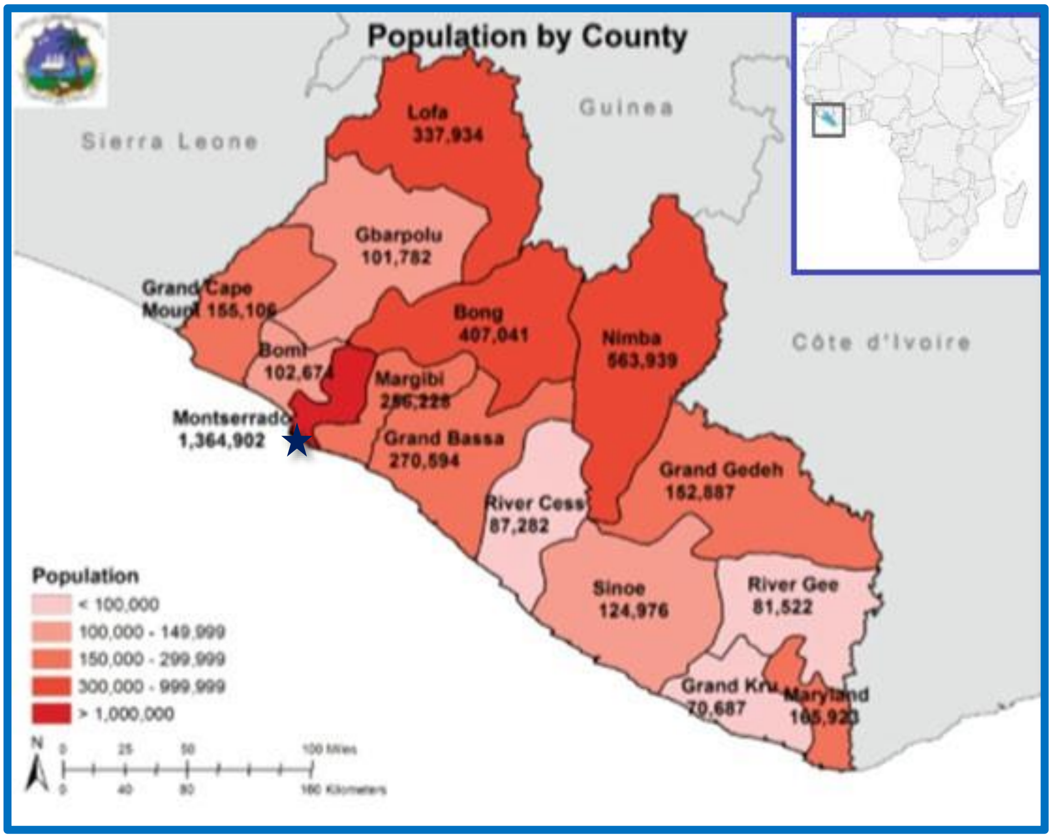

FIGURE 4: Liberia Population by County *(Modified by author from PAPD, 2018)*

<u>*3.2.2 Historical Context*</u>

The Republic of Liberia has a complicated history, one that is heavily entangled with the United States, marginalization, and conflict (Vinck et al., 2011). Sixteen indigenous ethnic groups comprise approximately 95% of the population, and many of whom have ancestral ties to the land that dates back centuries (Peterson, 2016). The remaining 5% consists of Americo-Liberians, the historic ruling class, and the descendants of formerly enslaved people from the United States and Caribbean, who arrived in the modern-day country starting in 1822 (Peterson, 2016). After gaining independence from the American Colonization Society in 1847, Americo-Liberians governed the country under a one-party political system for 133 years and operated virtually a segregated society that was modeled after the U.S. (Vinck et al., 2011). During this time ethnic groups and indigenous people were excluded from serving in politics, restricted from owning land, and not officially recognized as citizens of the nation until 1904 (Vinck et al., 2011).

With the capital city situated on the coast, and Americo-Liberians owning and occupying land mainly along the coastline, little attention was paid to the hinterlands in much of the 20^{th} century, which severely stunted economic development in the rural parts of the country (Vinck et al., 2011). Instead, large-scale land concessions with foreign corporations were established, which further removed indigenous people from their ancestral lands and concentrated wealth in the hands of urban elites (Peterson, 2016; PAPD, 2018). The most noteworthy agreement came in 1926 when the US-based Firestone Tire and Rubber Company laid claim to "over 4% of the territory for the world's largest rubber plantation" (Vinck et al., 2011). Lucrative land concessions and access to ports stimulated the extractive industries and export-oriented economy, which experienced rapid growth following World War II, and enabled the country to supply urban centers with imported goods such as rice – the staple food (Monke, 1979).

Rice importation markedly increased between the 1960s and the mid-1970s, tallying an estimated 22% of national consumption by 1976 (Monke, 1979). In 1979, over a growing concern of dependence on imports for the country's primary staple, the Minister of Agriculture proposed a price hike for imported rice with the hopes of triggering an expansion in domestic production. Instead, this proposal brought immense public backlash, stirring civil unrests and eventually chaos in what were later referred to as the '1979 rice riots' (Shor, 2012). This policy decision was widely viewed as corruption for personal gain and ushered in a wave of politically motivated executions and a coup d'état orchestrated by indigenous army sergeant Samuel Doe (Peterson, 2016). The Americo-Liberian oligarchy came to an end with Doe's presidency in 1980, but instability in the country persisted for almost a decade under his inexperienced leadership and would serve as the kindling to ignite the 14-year civil war (Vinck et al., 2011).

Between 1989 and 2003 the Liberian economy totally collapsed and more than a quarter-million people were killed while opposing political factions vied for power (Gbowee, 2011). A preeminent figure at this time was American educated Charles Taylor, who helped to violently overthrow Samuel Doe in an armed rebellion in 1990 and took control of valuable resources in the country's interior until his presidential election in 1997 (Vinck et al., 2011). In addition to the devastating toll on human life, massive urban migration occurred and one-third of the population was internally displaced, with the majority of conflict taking place in rural areas (Gbowee, 2011). During the civil war, the agriculture sector crumbled entirely and the production of cereal grains plummeted (**FIGURE 5**) as households were looted, farmland was abandoned, livestock were consumed, and what infrastructure had existed prior to the conflict was left in ruins (Peterson, 2016; Moore, 2017). The unconscionable war engulfed the whole of Liberia, sparing no one, and obliterated any prospects for agricultural modernity and economic development, and in many ways further bound Liberians to imported rice and poverty.

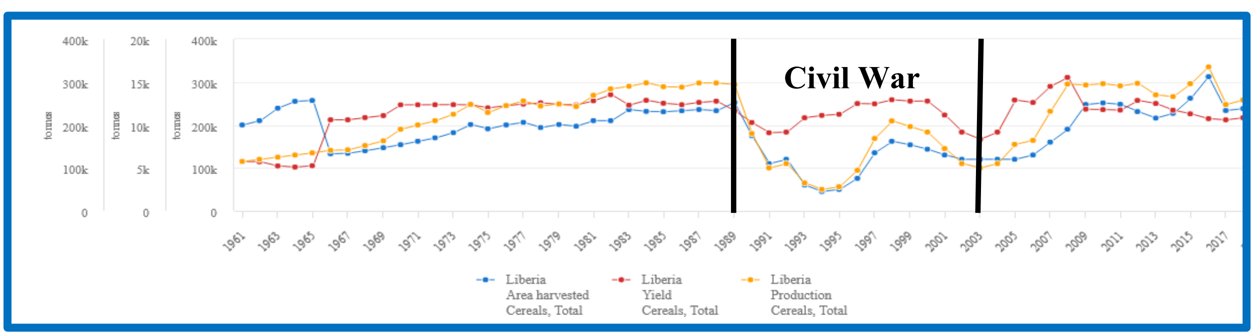

FIGURE 5: Total Cereal Production for Liberia *(Modified by author from FAOSTAT, 2022)*

3.2.3 The National Staple

Liberians have an intimate relationship with rice; the grain is eaten with every meal of the day and at times is the only source of daily calories. According to the United Nations Development Programme (UNDP), Liberians consume over 133 kilograms of milled rice annually – a per capita quantity greater than any other country in Africa (UNDP, 2022b). Rice makes up nearly 85% of the country's caloric intake (EAT, 2015) and on average it accounts for more than 22% of annual household spending (PAPD, 2018). As the primary staple, supply of rice is vital to national food security, but like many countries in West Africa consumption increasingly exceeds domestic rice production (Soullier et al., 2020). Hence, importing rice is essential to meet the national demand, and to ensure this small country of 5 million persons is an attractive market for rice exporters, the government has limited trade barriers and maintains a duty-free import policy on the grain (EAT, 2015). National data shows imported rice accounting for almost two-thirds of the country's total rice consumption (PAPD, 2018), but this overreliance on international suppliers for primary staple has led to manifold consequences for the people and government of Liberia (Soullier et al., 2020).

First and foremost, the price of rice in country is dictated by external market forces. Though imports are meant to provide consumers – primarily those in urban areas – with some stability, the current structure exposes them to global price volatility and leaves Liberians vulnerable to supply-chain disruptions. Issues such as the global food crisis of 2008 (Arouna et al., 2021), the Ebola outbreak in 2014 (Murphy et al., 2016), or the recent COVID-19 pandemic (Beckman et al., 2021) directly impact the price of rice in the country and exacerbate hunger. Secondly, imports constrain the national budget. In recent years, the government has expereinced an uptick in external debt, rising from 11% to 22.7% of the GDP between 2012 and 2017, and under a business-as-usual scenario this debt is expected to surpass 40% by 2023 (PAPD, 2018). The import bill for rice alone costs the government of Liberia an estimated 200 million USD per annum (Sigman & Davis, 2017; AfricaRice, 2020). Thirdly, imports hinder the competitiveness of domestic rice producers as grain from the U.S., India, and China saturate local markets and lowers net return for Liberian farmers. Consequently, between 2009 and 2019 the average annual growth of domestic rice production was -1.3%. Conversely, the average annual growth of rice importation was +7.4%. Meanwhile, hunger in Liberia increased by 3.2% over the same period of time (Soullier et al., 2020). This dependence on imports for the staple food creates a confluence of adverse effects for economic development by dis-incentivizing farmers to increase production, and inhibiting rice-related on-and off-farm employment opportunities in post-harvest processing and value-chain activities. As a consequence, Liberia's population faces elevated risk of price shock, food insecurity, and poverty. Additionally, the import policy poses a two-fold burden on the national budget with quantifiable costs for rice purchases and more difficult to quantify opportunity costs of lost domestic production and income-generation.

3.2.4 Rice Cultivation

While post-conflict Liberia is marred with infrastructural woes, increasing reliance on aid and imports, and high rates of food insecurity, chronic poverty, and urbanization, the country holds a wealth of natural resources and vast potential for agriculture-led economic development. Liberia encompasses 9.8 million hectares of lush, green topography, of which some 47% is arable land (Murphy et al., 2016). Moreover, it is home to immense biodiversity, rich and fertile soils, and abundant annual precipitation, which present ideal circumstances for farmers to grow multiple crops and harvests throughout the year (Moore, 2017). The agriculture sector is already a crucial part of the economy, contributing up to 26% of the real GDP; however, the lion's share comes from cash crops destined for export markets such as rubber, palm oil, and cocoa (LISGIS, 2017;

PAPD, 2018). Indeed, over the half-last century, food crops have been much less of a priority for commercial production, but the widening food deficit has stoked interests for self-sufficiency in the national staple.

Prior to the 1960s, almost all rice consumed in Liberia was domestically produced (Monke, 1979). In fact, farmers have grown rice across this landscape for centuries with cultivation taking place in each of the three major agroecological zones: the coastal plains, upland tropical forests, and lowland tropical forests (Peterson, 2016). Today, rice is among the most widely cultivated food crops in Liberia with around 74% of farming households producing it, although, mainly for subsistence purposes (LISGIS, 2017). Despite a favorable climate and environment for raising rice, production is stubbornly low – earning a meager national average of 1.26 metric tons per hectare in 2016 (LISGIS, 2017). Over the past 4 decades Liberian farmers have experienced only a marginal increase in yields, as indicated by the national average of 1.22 metric tons per hectare achieved in 1976 (Monke, 1979). A multitude of factors have contributed to the stagnation in rice production, but perhaps the most detrimental has been the traditional preference for upland rice grown with shifting (*slash-and-burn*) cultivation practices. Uplands account for roughly 90% of the total rice-producing area in Liberia with lowlands accounting for about 6% to 9% (Monke, 1979; Styger & Traoré, 2018). However, slash-and-burn cultivation is a key driver of deforestation, and is depleting the essential natural resources, disrupting vital ecosystem services, and threatening biodiversity in the country. Moreover, upland areas are highly susceptible to declining productivity over time and unsustainable for cultivation due to topsoil loss and erosion. Lowlands, on the other hand, are characterized by nutrient-rich topsoil accumulation and have significant advantages for irrigated cultivation. Lowland areas make up around 6% (588,000 hectares) of Liberia's total land mass (Murphy et al., 2016) and, at present, they are seriously underutilized in rice production. That said, lowland rice cultivation is not a novel concept for Liberian farmers as various investments were made in lowland areas in the 1960s and 1970s (Monke, 1979), though projects were largely abandoned after infrastructure fell into disrepair during the war (Moore, 2017). The International Fund for Agricultural Development estimates 600,000 hectares of the country's available arable land is unused (IFAD, 2019) with much of that being in lowland areas. This alone could produce enough rice to meet the national demand at a rate of 1.26 metric tons per hectare, but if coupled with SRI, these areas have the potential for yields far beyond the current national average, which can open the door for agriculture-mediated economic growth and livelihood diversification.

3.3 The Community of Hope Agriculture Project

One organization to have realized the untapped potential of the country's lowlands is the Community of Hope Agriculture Project (CHAP). This Liberian non-governmental organization, led by Reverend Robert S.M. Bimba, has been a staunch proponent of lowland rehabilitation since 2008. CHAP's mission is to create sustainable peace and prosperity in Liberia through agricultural development programming, focusing its efforts primarily on farmer advisory services for lowland rice cultivation and post-harvest processing. Over the years, CHAP has amassed an impressive track record working with diverse actors from public sector institutions, private entities, civil society groups, and international donors to improve livelihoods in rural and urban communities. In 2012, CHAP began promoting SRI in the country using in-field trainings and demonstrations, and since then, the organization has played a central role in the diffusion of this production system throughout Liberia. This dedication led to CHAP being named the focal point for SRI in Liberia during the 13-country SRI initiative under the West Africa Agriculture Productivity Program from 2014 to 2016 (Styger & Traoré, 2018); and their efforts have stopped there, as CHAP continues to champion SRI with various stakeholders through capacity building projects, mass media advocacy, and public outreach campaigns.

The organization is keenly aware of the multidimensional challenges Liberia is facing and understands the importance of rice in the society and economy. Therefore, along with its mission to improve domestic rice productivity and processing, CHAP is cultivating opportunities for youth engagement in their programming and inspiring the next generation of Liberians to pursue rice self-sufficiency. The organization views the country's rich endowment of natural resources and its demographic dividend as complementary assets that together can build a brighter future. In recent years, CHAP has established a burgeoning internship program that brings together students and graduates from local universities to gain hands-on learning experience with SRI. This program equips young people with practical knowledge and entrepreneurial skills in agricultural production and post-harvest activities such as processing and marketing. The goal is to provide education and employment opportunities to the youth to help transition farmers in the country from subsistence to commercial farming. This is done by creating prospects for young people to become field agents and development practitioners and exciting them about the potential of agricultural development while instilling the mindset of 'farming as a business.'

CHAP holds a diverse portfolio of implemented programs and provides a growing network of over 15,000 smallholder farmers with agricultural advisory services (SRI-Rice, 2022b). The organization has worked with international institutions including Africare, AfricaRice, BRAC, Cornell University, FAO, IFAD, JICA, USAID, and the World Bank, among others. Moreover, it regularly participates in national dialogue and collaborates with governmental ministries to inform decision-making with regard to agriculture in Liberia. CHAP is a highly influential stakeholder in the national rice sector and its commitment to agriculture-led economic growth facilitated by an expansion of lowland rice production and the transition to SRI management practices made it an attractive partner for this case study. With years of experience implementing SRI projects, and a robust network of farmers and field agents across the country, CHAP provided invaluable insights into relevant history, socio-cultural and policy factors, program successes and challenges, and logistical support for a series of farmer interviews and community focus group meetings.

CHAPTER 4: STUDY DESIGN AND FINDINGS

4.1 Rationale

There is a strong affinity for rice in Liberia's food culture, and the System of Rice Intensification (SRI) was introduced nearly a decade ago to help raise domestic productivity. Since then, various development initiatives have sought to scale up the production system in Liberia, however, no studies to date have thoroughly investigated the impact it has on farming livelihoods in the country. Consequently, very little is known about the perceptions and attitudes of rice farmers toward the alternative practices in cultivation. The only data comes from other rice-producing countries in West Africa, and given the diversity of farmers, farming systems, and agroecology of the region, a close examination is needed to better understand farmer experience in this specific context. The research in this chapter assesses how farmers comprehend the SRI method, what factors influence the adoption of SRI practices, and identifies the primary barriers limiting farmer uptake. This case study intends to fill the knowledge gap in the current SRI literature and shed new light on the experience of Liberian farmers with this production system.

4.2 Methodology

Qualitative research methods were used in this study to collect data from farmers in six counties across Liberia (**FIGURE 6**). Semi-structured interviews and focus group discussions were conducted with individual farmers as well as members of informal working groups, farming associations, and registered cooperatives. Surveys and questionnaires enabled farmers to elaborate in detail on the impacts of SRI, their cultivation practices, and what they perceive as the major constraints of the methodology. Additionally, field observations and interviews with agricultural extension agents provided a much-needed insight to better understand the current state of the rice sector in Liberia. The overarching goal of this study is to inform decision-making in policy and practice with regard to this production system moving forward, and this is done by exploring three questions:

(1) How do farmers understand the SRI method?

(2) Why do farmers adopt the SRI method?

(3) What types of support are most valued by farmers?

The Community of Hope Agriculture Project (CHAP) served as a key informant in this study and their field agents were critically essential for identifying communities and farmers with knowledge of SRI and organizing meetings with local stakeholders. The primary data used in this study were collected through in-person visits during the months of June and July 2022.

FIGURE 6: Map of Liberia with Study Locations *(Created by author on Maps.me application)*

4.2.1 Study Parameters

To answer the exploratory questions above, the study population was defined as farmers with knowledge of SRI, and included adopters, dis-adopters, and non-adopters. The scope of this study was determined in collaboration with CHAP extension agents, and the researcher utilized the organization's network of farmers to collect data. The following counties where SRI has been promoted contributed to this study: Bomi, Grand Cape Mount, Lofa, Margibi, Montserrado, and Nimba. Altogether, these six counties account for over 58% of Liberia's domestic rice production, with Nimba County being the largest contributor and Bomi County the smallest (LISGIS, 2017). These counties were selected because of their importance to domestic rice production and the fact they are home to communities with a range of access to resources, services, and infrastructure. Some communities are relatively close to Monrovia and can be reached easily by commercial transportation due to good road conditions. Hence, farmers in these areas have better market linkages for seeds, equipment, inputs, and outputs. While other communities are much farther from the capital city and accessible only by footpaths, motorcycles, or difficult roads that become impassable during the rainy season, severely limiting farmer access to finance, markets, and essential services.

This study primarily focuses on farmers engaged in lowland rice cultivation, though some respondents also produced cassava, vegetables, and other crops, as well as perennial trees on the uplands. There is a great deal of heterogeneity in the lowland production, with some farmers and groups cultivating no more than one hectare of rice using limited tools, while others cultivate large areas (some over 150 hectares) aided by power tillers and mechanized processing. Traditionally, much of the rice grown in these areas is for household consumption with limited surplus being sold at local markets for income generation. However, some larger scale farmers in the region have more commercial-oriented operations. The objective in site identification was to include a diversity of farm sizes, agroecological conditions, and socio-economic profiles in order to compile data from an array of participants and gain a comprehensive understanding of farmer experience with SRI in a variety of settings.

4.2.2 Sampling

Between June and July 2022, twenty-four communities were selected to participate in this study and 125 farmers made contributions (**TABLE 2**). Because the study population needed to possess knowledge of SRI, purposive sampling was done with the help of key informants that could identify where communities had the prerequisite experience. These communities ranged in population and geographic location, some within urban centers and others were in more isolated rural areas. Naturally, this influenced the structure of farming among participants, as some were individual farmers who could hire labor throughout the year, some were members of an informal working group, some were organized as a community-based association, and some belonged to a cooperative having substantial membership.

Prior to each community visit, local authorities and community leaders were given notice so farmers could be recruited. Farmers were selected based on their knowledge of SRI and their willingness to be participate in the study. While all farmers were involved in rice cultivation at the time of data collection, actively practicing SRI was not required to participate. Furthermore, since rice cultivation in Liberia includes labor inputs from both men and women it was essential to have adequate representation and participation of women. This sampling criteria facilitated inclusive dialogue in focus groups and the amalgamation of farmers in this study helped to increase the reliability of findings.

TABLE 2: Site Selection and Sampling

	County	Community	# Farmers Interviewed	Data Collection
1	Bomi	Levummah	9	FGD
	Bomi	Burphy Town	15	FGD
	Bomi	Klay	1	SSI
	Bomi	Tubmanburg	7	FGD
2	Grand Cape Mount	Benda	7	FGD
	Grand Cape Mount	Gonelor	10	FGD
	Grand Cape Mount	Sanjamana	14	FGD
3	Lofa	Mawoe Kama	1	SSI
	Lofa	Shelloe	1	SSI
	Lofa	Konduma	1	SSI
	Lofa	Kundu	3	SSI
	Lofa	Sayanin	1	SSI
	Lofa	Mayor River	1	SSI
	Lofa	Kelima Pombor	6	FGD
	Lofa	Konabeh Kormba	1	SSI
	Lofa	Keledu	1	SSI
	Lofa	Kpandu	1	SSI
4	Margibi	Kollie Kaine	1	SSI
5	Montserrado	Mount Barclay	1	SSI
	Montserrado	Fahnseh Town	12	FGD
	Montserrado	McGill Farm	12	FGD
6	Nimba	Ganta	1	SSI
	Nimba	New Gbasselah	2	SSI
	Nimba	Gbedin	16	FGD
Total	**6**	**24**	**125**	**FGD = 10 / SSI = 17**

(Quade, 2022)

4.2.3 Data Collection

This study used qualitative research methods to collect data through in-person interactions and observations, namely, semi-structured interviews and focus group discussions (FGDs). These methods were chosen to provide opportunities for participants to give in-depth accounts of their experience, as participant narratives reveal nuanced insights rarely found through conventional surveys and quantitative data analysis alone. Surveys were, however, useful for collecting general information about agricultural production at each site, and to record farmer knowledge with regard to SRI. Immediately prior to the start of data collection, questionnaires were field-tested with non-participant farmers and CHAP extension agents to ensure cultural sensitivity and locally applicable vernacular. While interviews and focus groups were conducted in English in all communities, some local adaptations to questions were made to account for regional dialect. In total, 10 FGDs (N = 108 total farmers) took place across five counties and 17 semi-structured interviews (N = 17 total farmers) were held in five counties. One designated CHAP extension agent accompanied the researcher to all sites and helped in the facilitation of these sessions.

The decision of whether to conduct an interview or focus group depended on the number of farmers that had been recruited with knowledge of SRI. Focus groups were arranged when six or more farmers in one site could participate in a discussion, and these sessions generally lasted between one and two hours. The questionnaire in focus groups consisted of 13 specific questions and was designed exclusively to facilitate dialogue and explore farmer experience with SRI while accumulating feedback from numerous perspectives (**APPENDIX A**). A few probing questions were integrated into these sessions but used sparingly, only to encourage further discussion among participants for the purpose of getting more detailed explanations in responses. This tool proved effective for reaching either a consensus or disagreement, both of which informed the data collected in other aspects of this study.

Semi-structured interviews, on the other hand, were conducted with individual farmers, and captured robust data through an open-ended questionnaire. This data collection tool was designed to elicit thoughtful and complex responses from single participants in a conversational format. The survey was developed as a guideline with three primary topics comprising over 25 questions and follow-up probes (**APPENDIX B**). Rather than a predefined script to follow, the researcher would ask questions based on the participant's previous answers and moved freely between topics and questions pertaining to farming practices, the SRI method, and social capital. Though semi-structured interviews were limited to just one participant per session and were shorter than focus groups, usually lasting between 30 minutes to one hour, this tool produced an immense volume of data that supplemented knowledge gained elsewhere.

In addition to semi-structured interviews and FGDs, field visits and observations also contributed to data collection. Most farmers were eager to show their rice fields after completing an interview or focus groups to offer visual evidence with regard to the issues noted in discussions. Comments made during these field visits often complemented the data and information gathered during sessions, and illustrated a vivid picture of the farming conditions in Liberia and the major challenges farmers face. Moreover, conversations with key informants and agricultural extension agents further contributed to this study, and this additional layer of data created another vantage point for analysis and enabled a deeper understanding of the Liberian rice sector as a whole.

4.2.4 Data Management and Analysis

All responses given by participant farmers were recorded in field notes during interviews and focus groups. At the end of each day, the researcher consulted with the designated CHAP extension agent and together they discussed takeaways from each session. The researcher then reviewed the recordings to verify data and elaborate in more detail while the information was still current. This process included making additional notes pertaining to the community and its access to roads, services, equipment, basic infrastructure, and urban centers; and observations were also noted with regard to participant attitudes, field visits, or any potential trends between communities. These field notes were then transcribed into Microsoft Word documents, coded, and stored safely in a password protected device.

While conducting interviews and focus groups, common themes began to emerge across communities. Early in data collection it became evident that participants experienced similar successes and challenges with SRI and in rice farming, more broadly. In qualitative research this recurring information is known as *saturation* – the point at which no new data are being found and, regardless of the wide-range of groups or individual participants, the researcher can be confident in developing categories for analysis, as nothing new is being learned with subsequent interviews (Glaser & Strauss, 1967). Saturation of some categories were largely consistent across counties, districts, communities, and farmers, and revealed true needs in rice production for both subsistence farmers and those more commercial-oriented.

Because this study used qualitative research, and the samples taken were relatively small, Microsoft Excel was used for analysis of data. First, the questionnaires were input manually into spreadsheets by the researcher; one for semi-structured interviews, one for focus groups, and one with overlapping questions from both data collection methods. Second, simple categorizing of responses was done to neatly organize the datasets for analysis. Third, frequency distributions and bivariate analyses were run to examine common patterns in the data. Finally, triangulation analysis was conducted by comparing the findings from data analysis with the comments of key informants and field observations. The findings organized in this paper discuss the investigated and emergent themes from this analysis.

4.2.5 Study Limitations

Although efforts were made to limit sampling bias, the timeline of data collection (June and July) coincided with the peak of Liberia's rainy season. This presented certain challenges for transportation and hindered data collection in some parts of the country. While the six counties sampled in this study were essential, as they represent a significant portion of the domestic rice production and are home to a wide spectrum of rice farmers, bad road conditions due to inclement weather rendered the southern and south eastern parts of Liberia inaccessible. Ideally, more time and access would have allowed for more stratified sampling to collect data from all ten counties where SRI had been promoted, but these limitations prohibited this from happening. Another potential limitation with regard to sampling includes the number of farmers that were recruited in each community. The total number of participants that contributed to this study varied from community to community, and given the travel time and costs to get to and from these areas, the decision to conduct semi-structured interviews or focus groups was determined largely at random rather than systematically. Furthermore, community leaders were used for recruitment and it is possible that some farmers with SRI experience may have been missed in the recruiting process or were unable to participate when data collection took place.

In addition to limitations in sampling, the data collection methods employed in this study were quite time-consuming, which limited the number of participants the researcher could meet with each day. Though qualitative methods were chosen specifically to produce robust data that would enhance the analysis of farmer experience with SRI, these methods required a substantial review and write-up process after each community visit, which imposed time constraints on the researcher. Moreover, findings from qualitative research typically have a high internal validity and accuracy due to interpersonal data collection methods, but these findings are often viewed as less reliable and generalizable as a result of a fewer participants. The saturation experienced in data collection helps address this reliability concern and built confidence in the researcher regarding the adequacy of sampling; however, the methods used still pose potential limitations.

Lastly, one cannot rule out the possible introduction of bias in focus group discussions and semi-structured interviews. There is an unknown degree of influence or perceived power dynamics in semi-structured interviews between the researcher and the participant. Likewise, in focus groups the responses provided by an individual may be influenced by social dynamics or other participants in the discussion. Though serious efforts were made in all facets of this research to eliminate the introduction of bias, these issues must be considered.

4.3 Study Findings

The results presented in this section detail the investigated and emergent themes from analysis of data collected through semi-structured interviews and focus group discussions. These themes include farmer perceptions of SRI with regard to the methodology and its benefits, as well as the challenges rice farmers face with implementation. Select quotes from interview and focus group transcripts are used to support the patterns discovered in the larger dataset and to provide further context to these issues. The findings from this analysis illustrate the importance of rice as a primary source of food security and livelihood in Liberia and emphasize the major barriers to raising rice production in the country.

4.3.1 How do farmers understand the SRI method?

Responses in semi-structured interviews and focus groups showed little to no variation in farmer perceptions of the SRI method. Overwhelmingly, farmers in both sessions reported that SRI increased their rice yields (100% of participants) but demanded more labor than traditional cultivation practices (80% of participants). For many, the increase in yield influenced their belief that SRI was a better way of producing rice compared to traditional practices, but for others the increase in labor played a significant role in their decision to discontinue this production system. Three labels were assigned to categorize the 125 farmer participants based on their SRI production status at the time of data collection: (1) adopters, (2) dis-adopters, and (3) non-adopters. In total, 54 participants were persistent SRI farming practitioners, 57 participants had tried SRI in the past but reverted to their previous practices, and 14 participants had theoretical SRI knowledge but no practical experience implementing it. Accordingly, 43.2% of the overall participants in this study were adopters, 45.6% were dis-adopters, and 11.2% were non-adopters (**TABLE 3**).

> *"With SRI you use less seed and get more yield. There is also better weed management because of the spacing, but that does require more man power. Traditional [clump] transplanting takes less time and less labor and you get less yield. SRI takes more time and more labor and you get more yield. Land preparation is also different for SRI. Fields need to be laid out well and you only transplant one seedling, and not [in] clumps."*
> – Male farmer, SSI, Lofa County

TABLE 3: Participant Category and Data Collection Method

	Adopter		**Dis-adopter**		**Non-adopter**		**Total**	
FGD	44	40.7%	52	48.1%	12	11.1%	108	100.0%
SSI	10	58.8%	5	29.4%	2	11.8%	17	100.0%
Total	54	43.2%	57	45.6%	14	11.2%	125	100.0%

(Quade, 2022)

While participants unanimously reported increases in yield with SRI, knowledge of this production system varied substantially among data collection methods. Farmer knowledge of SRI was evaluated based on the understanding of a minimum three out of the six main practices, which included: (1) early establishment (8 to 15 days old) of seedlings, (2) transplanting single seedlings, (3) using wider plant spacing, (4) controlling water carefully, (5) organic matter additions, and (6) mechanical weeding. The collective knowledge of these six practices was relatively low, and the participants in focus group scored lower on average than those in semi-structured interviews, as indicated by the mean understanding of 3.4 and 4.0 out of six practices, respectively. However, when disaggregating farmer knowledge on whether participants were adopters or dis-adopters, this gap interestingly disappears, with both categories scoring a mean understanding of 3.5 practices.

The most commonly understood SRI practices included using wider plant spacing, controlling water carefully, and transplanting single seedlings (**FIGURE 7**).

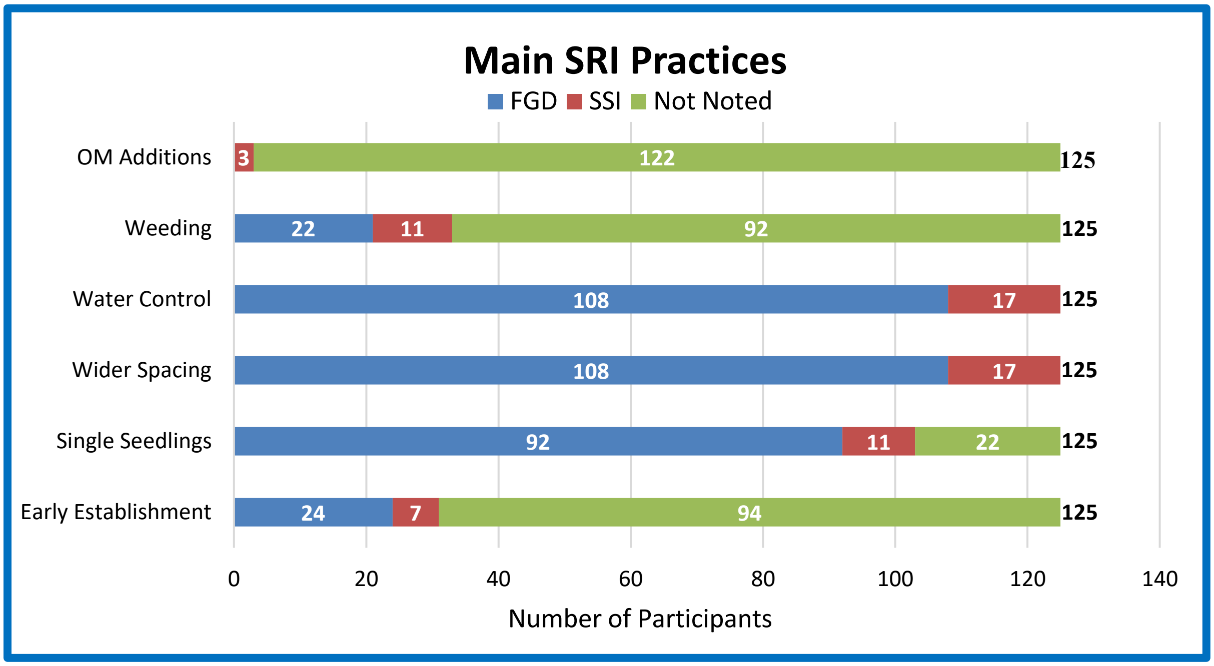

FIGURE 7: Participant Comprehension of the SRI Method (*Quade, 2022)*

The farmers surveyed in this study were asked to explain *"How is SRI different than what you were doing before?*" to which a variety of responses were given, though generally the replies combined elements pertaining to transplanting, managing water, and achieving higher yields. Later in the sessions farmers were asked which of the SRI practices they believed result in greater yield. Interestingly, the two most well-known practices were noted by participants equally. Wider plant spacing was recognized to improve plant growth and increase grain production per plant, while applying less water early in the season was understood to increase the number of tillers. The astute observations demonstrated farmer comprehension of these individual practices and their relative benefits, yet comprehensive knowledge of the production system as a whole and its synergistic principles was lacking, and virtually absent in farmer understanding was the principle of building soil fertility, with just three participants discussing organic matter additions and the integral role of soil management in SRI.

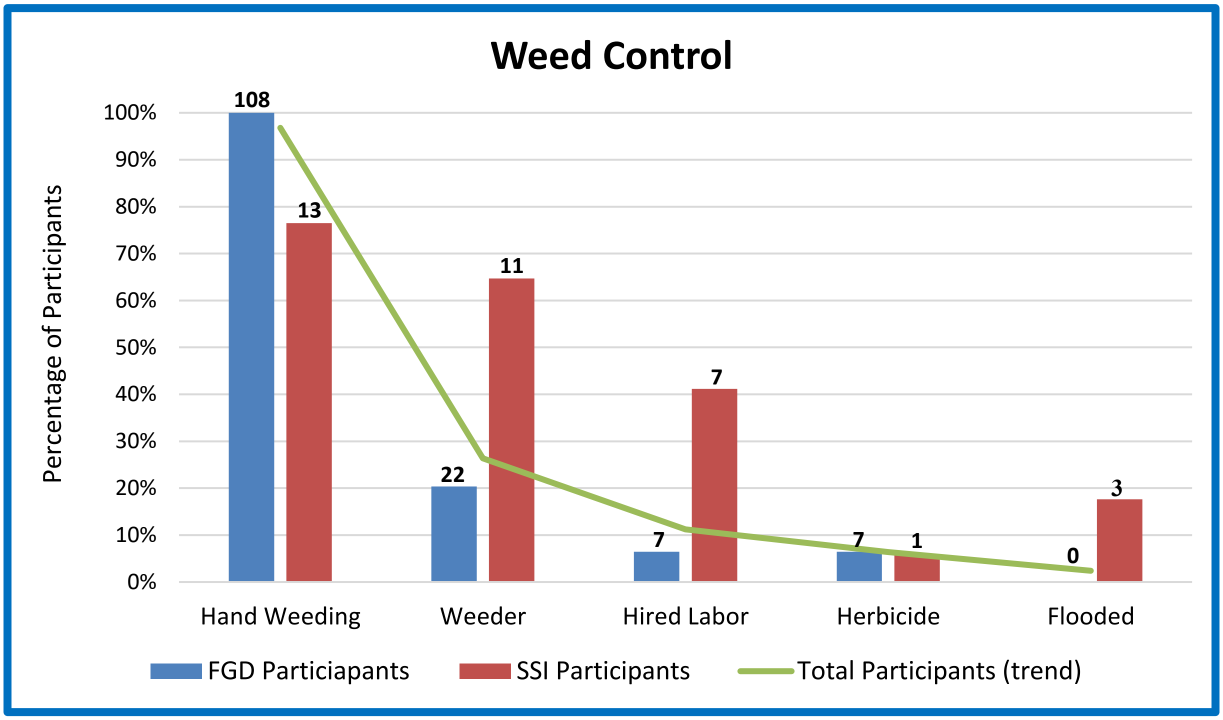

FIGURE 8: Participant Weed Control Methods (*Quade, 2022)*

Weed control using a mechanical weeder was another practice rarely mentioned and not well understood. Although 36% of participants attested to experiencing more weeds with SRI, just 22 out of the 108 participants (20.4%) in focus groups had used a mechanical weeder in their rice fields. While the infrequent use of a mechanical weeder was mainly due to limited access of this equipment, of those 22 with access to a weeder 100% reported their preference for hand weeding. Conversely, 11 out of the 17 participants (64.7%) in semi-structured interviews had access to a mechanical weeder, eight of which reported a positive experience. The concept of using a mechanical implement to manage weeds in rice fields was relatively unfamiliar among the participants, or was unpopular due to the perception of this activity being more time-consuming and requiring additional labor opposed to hand weeding. In both data collection methods, hand weeding was the most frequently reported weed control strategy. It was brought up in some combination of weed management practices by 100% of participants in focus groups and over three-quarters of those in semi-structured interviews (**FIGURE 8**). Sadly, only one farmer out of the 125 surveyed in this study embraced the use of a mechanical weeder and understood the diverse benefits of soil aeration with regular weeding.

Additional labor associated with SRI was a key factor that influenced farmer perceptions of this methodology. In focus groups, 79.2% of participants reported labor-intensive practices as a challenge with SRI implementation, while 80% of those in semi-structured interviews noted similar responses. According to participants in these sessions, the major labor-related burden was land preparation, followed by transplanting and then weeding, as these activities were reported 64.8%, 36%, and 26.4% of the time, respectively. The majority of farmers in semi-structured interviews cited land preparation as the biggest challenge (70.6%), while a smaller segment of those interviewed noted problems in transplanting (41.2%). Though more than three-quarters of the participants in semi-structured interviews had experience with rice transplanting prior to learning SRI, the traditional method they used was much less calculated. Thus, farmers reportedly spent more time and labor carefully handling seedlings and precisely measuring the width between single plants during rice transplanting. Whereas those in focus groups primarily made the transition to SRI from broadcasting cultivation, which requires much less management before planting and throughout the growing season. Therefore, these farmers noted, in comparison to broadcasting, SRI demanded more labor with regard to land preparation (63.9%), as well as transplanting (35.2%) and weeding (29.6%).

Labor-saving devices such as power tillers were observed in some of the market-oriented sites which alleviated the drudgery in land preparation for a select few, although, farmers in these locations typically perceived labor difficulties in transplanting and weeding, as a result of larger production areas. Farmers growing rice primarily for subsistence purposes made up the bulk of those burdened by land preparation, as they had less access to equipment and mechanization for brushing and tilling the soil. Overall, 11 out of the 17 participants (64.7%) in semi-structured interviews and 23 out of the 108 participants (21.3%) in focus groups had access to a power tiller, but curiously issues in land preparation were reported at a lower rate in focus groups.

> *"The biggest challenge with SRI is land preparation. In the rainy season, the lowland soil is heavy and difficult to plow; and only using hand tools makes it back-breaking work. Machinery, like a power tiller, is needed for land preparation, or it's not worth it."*
> – Female farmer, FGD, Bomi County

4.3.2 Why do farmers adopt the SRI method?

Responses throughout semi-structured interviews and focus groups were quite revealing as to why farmers chose to adopt the SRI methodology. The general consensus, regardless of the data collection method, was that SRI produced more yield and required less seed than traditional practices. The unequivocal reply to the question *"What encouraged you to try SRI on your farm?"* was "*To get more yield."*; and when a follow-up question was posed to participants asking if they personally experienced a yield increase after switching to SRI, the unanimous answer was *"Yes!"* Because farmers in this study grew rice predominantly for subsistence (100% of the participants stated at least a portion of cultivated rice went towards household consumption) the underlying motivation for trying this production system was to improve yields for increased food security. The majority of participants (59.3%) in focus groups produced rice exclusively for household consumption (**FIGURE 9**), and 82 out of the 96 farmers (85.4%) in focus groups with practical

SRI experience said they achieved increases in yield that surpassed household consumption needs. Additionally, 42 participants (43.8%) noted their rice harvests more than doubled with SRI when compared to traditional cultivation practices. Members of one farming association claimed their yields went from 1.25 metric tons per hectare with broadcasting to 5 metric tons per hectare under SRI (*a 400% increase!*) while using one-fifth the seed previously needed to plant one hectare of land. For those in semi-structured interviews, 12 out of 15 participants (80%) with practical SRI experience stated their yields increased beyond household consumption needs, and seven of these participants (46.7%) noted their harvest more than doubled with SRI. In both sessions, farmers also commented on how SRI provided opportunities to grow rice more than two times per year, which further increased household food availability and the potential for income generation. Moreover, all farmers in this study reported drastic reductions in seed usage, up to 90% by one farmer's recollection – going from 100kg per hectare with broadcasting to 10kg per hectare with SRI.

> *"SRI is better than broadcasting because you plant less and you get more. It gives us rice for consumption, seed for next season, and extra for [selling in] the market… We now have more money to pay for our kids' school fees."*
> – Male farmer, FGD, Grand Cape Mount County

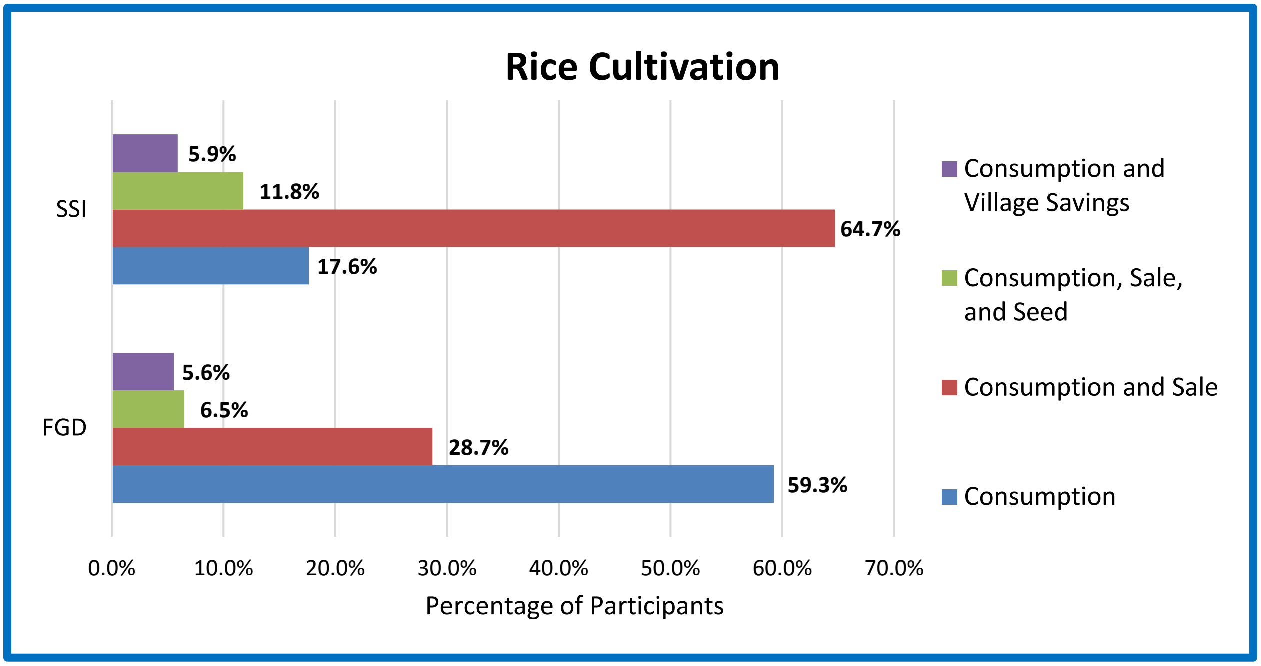

FIGURE 9: Participant Rice Cultivation Motivations (*Quade, 2022*)

Farmers described the benefits they experienced with SRI in various ways. For instance, one working group in Bomi County explained how improved rice productivity allowed them to diversify their crop production. Adaptations in cropping systems were explained by 24 out of 95 participants (25.3%) in focus groups that struggled with storing, processing, and marketing their surplus rice. For these farmers, SRI produced enough rice for household consumption and did so with less land than broadcasting. This enabled them to plant and grow more high-value vegetable crops for market, contributing to increased income and food security. Farmers in Nimba County mentioned how greater yields attributed to SRI helped them fulfill a contractual agreement to supply a school meal program, which benefit the entire community through income generation. Across the six counties surveyed, 86.7% of participants in semi-structured interviews and 62.5% of those in focus groups declared that SRI improved farm management and often commented on how the production system led to better record-keeping and accounting of seed, labor, and yield. This empowered many to transition from purely subsistence farming to '*farming as a business.'*

Aside from improved yield for increased food security and income, participants gave examples of social benefits experienced with SRI such as farmer-to-farmer support networks in the absence of formal extension services and some participants explained how SRI unified their community by bringing farmers together as collective to accomplish tasks like land preparation, transplanting, weeding, irrigating, and harvesting.

> *"There are opportunities for integrating rice with other crops such as vegetable on the bunds, and it lets you produce several crops over the year. SRI also brings people together to share ideas and it promotes better farm management. They say 'your footsteps are the fertilizer' and that is true with SRI because you are always in the field."*
> – Male farmer, SSI, Margibi County

4.3.3 What types of support are most valued by farmers?

The scope and population of this study provided an excellent opportunity to examine the factors that hinder implementation of SRI in Liberia. In both semi-structured interviews and focus groups, the question *"What are the biggest challenges with SRI?"* allowed farmers to explain the major impediments they faced. These challenges primarily dealt with infrastructure in cultivation and post-harvest that limited production as well as technical capacity and farmer comprehension of the SRI method. Five prominent barriers emerged from farmer responses, which included: labor-intensive practices, lack of technical support, water control, post-harvest storage and processing, and marketing (**FIGURE 10**). Time and again these issues were brought up in discussions and interviews, and expressed by adopters and dis-adopters alike.

As previously noted, increased labor demands influenced farmer perceptions of this production system, making labor the second most reported challenge among participants in this study. However, when looking closely at other responses from farmers that cited labor-intensive practices as a challenge, bivariate analysis indicated 58.3% of those in semi-structured interviews and 77.6% in focus groups faced other burdens in cultivation and post-harvest management. These additional obstacles that participants faced could provide another explanation as to the factors that influence dis-adoption. For instance, of the 46 dis-adopters in focus groups that noted labor as a major barrier, 100% also reported insufficient storage while 78.3% experienced marketing constraints. Because the majority of participants in focus groups grew rice solely for household consumption, and SRI produced yields greater than household needs, many of these farmers experienced new challenges in storing, processing, and marketing their surplus grain. As a result, post-harvest activities were the biggest barriers discussed in focus groups, and emphasized by adopters and dis-adopters at rates of 84.1% and 88.5% of the time, respectively. Participants in focus groups regularly debated amongst themselves the trade-offs with labor and yield and the challenges of selling rice in local markets. Many dis-adopters in focus groups described plentiful opportunities for expanding their production area – if only they could sell their harvest at the end of the season. Without strong market linkages the surplus rice generated with SRI, and the additional labor expended to produce it, was ultimately *"spoiled"* due to limited or inadequate storage and the inability to prevent post-harvest losses.

> *"Selling 'country rice' is a big challenge in the market. It's difficult to compete with the price of imported rice and many customers prefer the imported one over local rice. Currently, we sell only one cup at a time, and sometimes a small bag. Frankly speaking, we need more information on how to sell the local rice, so customers prefer ours over the imports."*
> – Male farmer, SSI, Nimba County

While labor, marketing, and post-harvest activities posed complex challenges for farmers that often interact with one another, water control was the most pervasive challenge experienced by all farmers in this study. Accordingly, 12 out of the 17 participants (70.6%) in semi-structured interviews and 94 out of the 108 participants (87%) in focus groups reported issues with water control. Because SRI has been promoted in Liberia's lowland areas, farmers routinely struggle to manage water during the rainy season (May through October) which coincides with the primary rice growing season. In semi-structured interviews, 60% of adopters, 80% of dis-adopters, and 100% of non-adopters reported water management as a major barrier for SRI implementation; and of those in focus groups, 95.5% of adopters, 76.9% of dis-adopters, 100% of non-adopters noted similar constraints. The severity of this issue was illuminated during field observations at the time of data collection. Dams and canals used for storing and distributing water for cultivation were routinely broken as a result of abundant rainfall, leaving rice fields and lowland areas inundated with water. Across all locations, farmers recognized water management as an essential part of the SRI method, but a lack of infrastructure to support intermittent irrigation hampered their ability to control water sufficiently.

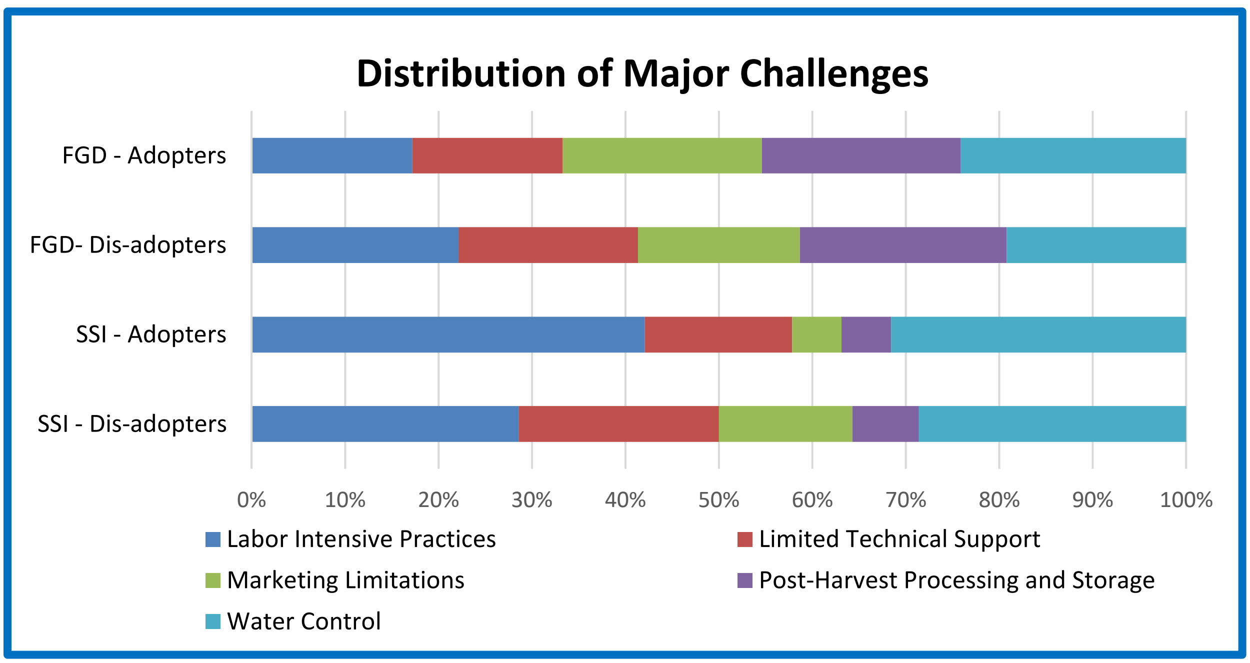

FIGURE 10: Participant Challenges with SRI Implementation *(Quade, 2022)*

Participants in semi-structured interviews were 1.7 times more likely than those in focus groups to report challenges pertaining to cultivation (labor and water). Whereas, participants in focus groups were 2.7 times more likely than those in semi-structured interviews to report issues regarding post-harvest (storage and marketing). This was primarily due to the market integration of these participants and their scale of rice production. Interestingly, one challenge consistently reported, regardless of the data collection method, was the limited technical support farmers received under the SRI method. Farmers in each of the six counties reportedly experienced new challenges with this production system they had never faced under traditional transplanting or broadcasting cultivation, and felt they needed regular technical support to overcome these issues. However, farmers cited significant barriers to getting the help they required, mainly infrequent visits from extension personnel and development practitioners. In focus groups, 63.9% of adopters and 76.9% of dis-adopters referenced the lack of technical support as a major challenge to SRI implementation. While participants in semi-structured interviews reported this issue to a lesser extent, still 30% of adopters and 60% of dis-adopters noted insufficient technical support with regard to SRI. Among those with practical SRI experience, limited technical support was reported more with the dis-adopters than adopters, but the non-adopters ranked limited technical support as a key impediment and one of the main reasons why they had not yet practiced SRI in their fields.

The final question posed to participants in semi-structured interviews and focus groups asked how training on SRI could be improved. Universally, all farmers stated they needed more opportunities for practical learning (100%). The majority of participants (71.2%) learned the SRI methodology by establishing a community demonstration plot with the guidance of an extension agent from the Community of Hope Agriculture Project (CHAP). For many, this was the only time they received technical support pertaining to SRI, but due to hands-on learning, the participants grasped most components of this production system with ease. However, because SRI involves multiple principles and practices, there was a relatively low retention of all the components, and comprehensive knowledge of the methodology was not well understood. Recognizing that more opportunities for training was a critical need amongst farmers, a follow-up question was asked to the participants regarding what, specifically, they would be interested in receiving more training on. The five most requested topics included: equipment and labor-saving devices, land preparation, water control, post-harvest activities and marketing, and weed management (**FIGURE 11**). Training on water control ranked the highest among all topics, with 65.7% of focus groups participants and 58.8% of semi-structured interview participants expressing their interest for more training. Land preparation was the second most requested topic while post-harvest activities and marketing was third. Analysis of these requests for additional training was consistent with field observations and the data collected throughout this study. Water control was the main challenge to SRI implementation experienced by participants, while labor-intensive practices – particularly in land preparation – heavily influenced the perceptions of this production system, and the limited access to post-harvest infrastructure and markets played major roles in their decision to continue with SRI, or abandon it.

> *"To improve SRI in the field, you have to get knowledge from training. At least once, if not twice a year, so you can remember all the steps and help others, too."*
> – Male farmer, SSI, Lofa County

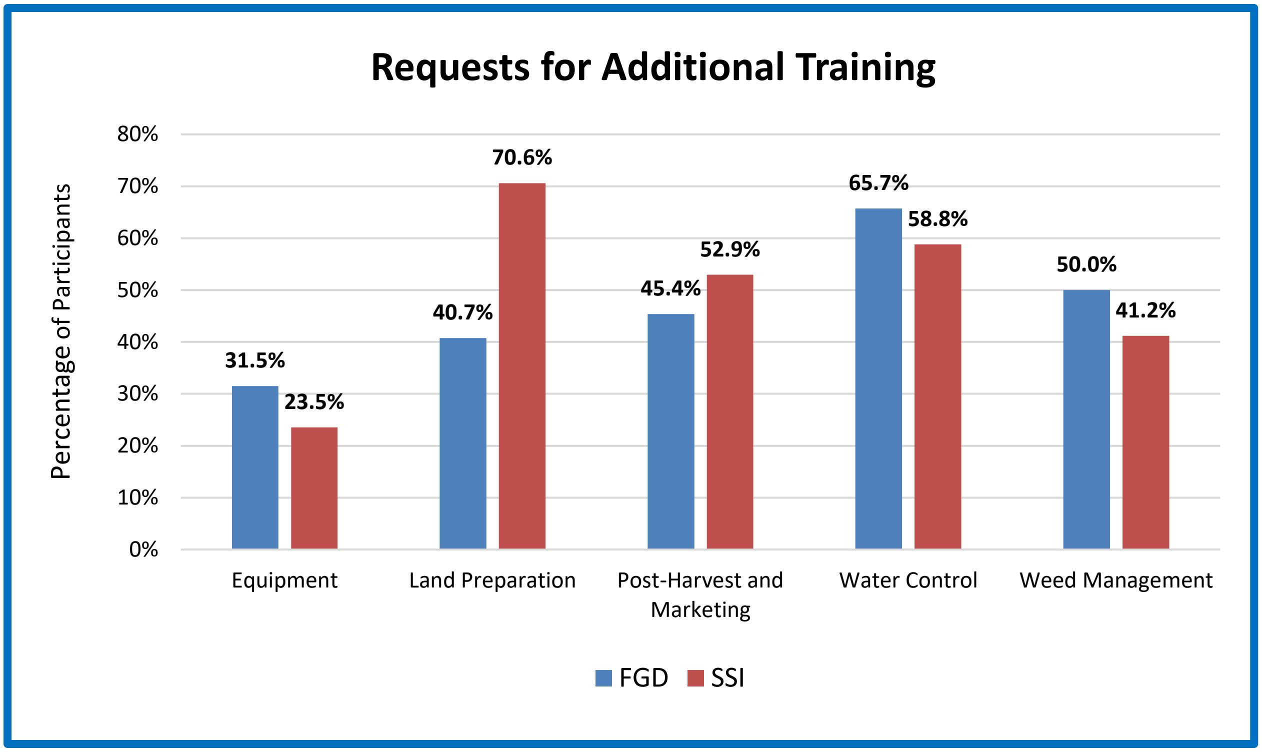

FIGURE 11: Participant Training Needs *(Quade, 2022)*

Discussion 4.4

The System of Rice Intensification (SRI) has impacted the livelihoods of Liberian farmers in myriad ways. Data analysis shows a wide-range of benefits in terms of food security, income, and social cohesion, but it also demonstrates complex barriers that rice farmers experience with this production system. Labor-intensive practices such as land preparation, transplanting, and weeding pose additional burdens for farmers and a substantial learning curve which influences behavior change. Meanwhile, the development and maintenance of water control infrastructure proved a formidable challenge for the majority of participants in this study. These alternative cultivation practices, along with limited technical support to help navigate this uncharted territory, pushed many farmers to discontinue the SRI method. For those that persevered through challenges in cultivation, the increased yield exacerbated challenges related to inadequate storage capacity, weak post-harvest management practices, and undependable markets for surplus rice. Roughly half of the farmers with practical SRI experience in this study reported hurdles too large to justify continuous adoption, while the other half indicated there is a way.

The qualitative methods used for primary data collection revealed interesting differences between the participants in semi-structured interviews and focus groups. Generally, farmers that contributed to focus group discussions were much less enthusiastic about SRI, as demonstrated by a lower adoption rate, a lower score regarding SRI knowledge, and a higher prevalence of reported challenges. Additionally, when compared to their counterparts in semi-structured interviews, those in focus groups had less experience with improved rice cultivation. These participants were mainly transitioning out of broadcasting cultivation and were still producing rice primarily for subsistence purposes. Furthermore, while those in focus groups experienced rice yield increases that exceeded household consumption needs at a higher rate than participants in semi-structured interviews, they were almost three times more likely to report post-harvest and marketing constraints, regardless if they were adopters or dis-adopters. On the other hand, those in semi-structured interviews were generally more experienced farmers, with the majority producing rice for both consumption and sale while holding a greater understanding of the SRI method and a higher propensity to try new practices. Typically, the farmers in semi-structured interviews also had more access to equipment such as mechanical weeders and power tillers as well as financial resources for hiring labor; however, they were more likely than those in focus groups to report challenges with labor-intensive practices and land preparation due to increased costs.

There were clear differences between the farmers in semi-structured interviews and those in focus group discussions, but regardless of data collection methods, trends emerged from analysis that highlighted the most significant opportunities and challenges for rice farmers in Liberia. The main takeaway from this research is that dramatic improvements in food security and economic development can be achieved with more support for SRI, specifically, with regard to technical capacity building, water infrastructure, and post-harvest activities and marketing. Throughout the study area participants holding practical SRI experience reported more yield when compared to traditional management practice (irrespective of their method of establishment, i.e., transplanting or broadcasting), and over 44% of these farmers claimed doubling (or more) their previous yields. Enhanced productivity led to more grain for consumption, seed, and market, and in some cases the diversification of crop production and livelihood opportunities, despite a relatively low and partial comprehension of this methodology among respondents.

On average, the farmers in this study understood just 3.5 out of the six main SRI practices, and a mere 2.4% understood the importance of building soil fertility with organic matter additions. This ecological principle is crucial to the synergistic practices of SRI and provides enormous value for the long-term sustainability of rice production, yet the principle was virtually absent in the knowledge of participants. Elevating this principle in future trainings holds potential for further benefits in soil health, crop productivity, and input cost savings. Regular trainings are critical for practitioners to engage with farmers in the field, better understand the issues of priority concern, and further advance farmer comprehension and capacity for testing and evaluating new practices. Limited technical support was reported as a major challenge by more than 70% of the participants in this study. Scaling SRI adoption within and beyond the study area will require greater support and encouragement for farmers as they examine and test new management practices. There are many proven strategies for doing so – often building upon collective learning and farmer-to-farmer exchange of ideas and experience. Farmer capacity for adaptation and innovation around SRI principles has been widely documented elsewhere in the world. Making enhancement of that capacity a more explicit goal of the CHAP SRI program could result in a more prominent role for farmers in adapting SRI practices to work in the biophysical, social, and market context described in this study.

In addition to more frequent trainings on soil health and the SRI practices, farmers also demonstrated a need for assistance with water control. While training on water management is important, impacts will be limited without new investments in water infrastructure rehabilitation and upgrades. In Foya District of Lofa County, private companies and civil society organizations have come together to develop multiple reservoirs and irrigation schemes for farmers which has transformed the productivity among SRI farmers in this area. As noted above, water control was the most pervasive challenge farmers in Liberia experience with the implementation of SRI, and as a result it was well understood that more training and assistance is required in this area overall. However, more investments in the physical infrastructure for water control are a prerequisite to broad revitalization of lowland areas for rice cultivation. Such investments hold potential for dramatically increasing domestic rice production. The yield increases reported by farmers with practical experience in SRI suggest very favorable cost-benefit ratios for investments that allow for more effective water control.

Post-harvest processing, storage, and marketing were also among the biggest challenges farmers face with SRI, and commonly discussed in focus groups and semi-structured interviews. The lack of adequate storage frequently led to high rates of post-harvest loss, while limited processing facilities throughout the country left most farmers with no alternative but to use a mortar for milling their rice. Milling in this fashion is not only labor-intensive but increases broken rice grains and the potential introduction of impurities. Locally grown and milled rice is thus often viewed as inferior to imported rice. Direct market support in the form of contract buying and other linkages between producers and processors are crucial for raising rice productivity in Liberia, improving post-harvest handling and storage, and providing market access to regional farmers. Also, as SRI boosts yields local mills can run more consistently throughout the year, creating new opportunities for non-farm income and employment.

This investigation was conducted to answer three primary research questions: (1) *How do farmers understand the SRI method*? (2) *Why do farmers adopt the SRI method?* and (3) *What types of support are most valued by farmers?* The objective was to better understand SRI in Liberia through an assessment of farmer experience with this production system to evaluate the benefits it provides and identify the barriers that limit farmer uptake. This study intends to shed light on new information regarding farmer perceptions and attitudes toward this methodology and hopefully will lay the groundwork for future investigations in this field. While the goal of this paper is to inform decision-making with respect to policy and practice, continued research on SRI is needed in Liberia to explore the unanswered questions that arose throughout this investigation.

PART III - RECOMMENDATIONS

CHAPTER 5: POLICY

5.1 Summary

The System of Rice Intensification (SRI), as demonstrated throughout this paper, affords myriad benefits to Liberian farmers and households with substantial potential for the economy and society. This innovative approach to rice cultivation not only enhances the production of Liberia's primary staple, thus reducing its dependence on rice imports, but creates vast opportunities for harnessing the natural resources and demographic dividend of the country. Targeted government investment in Liberia's rice sector can remove some of the most important barriers to SRI adoption. The resulting improvements in productivity can decrease food costs and directly lower the prevalence of some forms of undernutrition in Liberia. Moreover, investing in this dynamic production system can stimulate growth in income generating activities and livelihood diversification, presenting new employment prospects for the youth and those economically disadvantaged. Increased rice yields brought with SRI cultivation enable farmers to produce surplus grain, and with more infrastructure in post-harvest storage and processing, this will positively impact trade and increase the demand for service-oriented occupations. Therefore, it is vital for the Government of Liberia to support food policy to improve rice productivity through SRI, as this can play a major role in ameliorating poverty and hunger while contributing to the structural transformation for economic development (Webb & Block, 2012).

In 2018, the Pro-Poor Agenda for Prosperity and Development (PAPD) was released, and in this four-pillar plan the Government of Liberia emphasized increasing the standard of living for all Liberians by: empowering the people, creating better economic opportunities, establishing trust and sustainable peace, and maintaining transparency for accountable governance. The PAPD offers detailed strategies for achieving a vision of national resilience by 2030. However, much of the attention for agricultural investment in this plan is focused on cash crops destined for export such as palm, rubber, and cocoa, and less consideration is paid to essential food crops such as rice. Targeting investments for export-oriented cash crops opposed to food crops for domestic consumption will ultimately have limited impact on food security and poverty reduction, which are the two most daunting development challenges. Government investment in rice farmers and SRI production, on the other hand, would directly address pillars one and two of the PAPD and have indirect benefits on pillars three and four as well. The recommendations provided below were guided by the experience of rice farmers who participated in this study and intend to complement the Government of Liberia's mission for rice self-sufficiency.

5.2 Recommendations for Policy Makers

1. **Increase public sector investment for irrigation and water control infrastructure in lowland rice cultivation.** Water control is one of the four essential SRI principles and it remains the primary barrier facing rice farmers throughout the country. Lowland areas in Liberia are natural catchment basins for water and nutrients, offering superb advantages for rice cultivation (and vegetables) compared to upland areas. Government investment in lowland irrigation projects and water control infrastructure, such as dams and canals, can significantly boost rice and agricultural productivity in the country, and empower farmers to fully utilize the abundant rainfall Liberia receives throughout the year. Infrastructure for water storage would create new possibilities for dry season farming and help reduce farmer vulnerabilities to the impacts of climate change and variable weather patterns.
2. **Establish a program that incentivizes rice farmer transition to SRI.** SRI creates broad economic, social, and environmental benefits in comparison to conventional and traditional rice production systems, however, it requires additional labor in the initial seasons and

there is a substantial learning curve for rice farmers. Establishing a program that provides a monetary incentive for practicing SRI would encourage more rice farmers to make the transition and continue implementing it, which would lead to long-term benefits for land stewardship and agricultural sustainability. In addition, rice yield increases stemming from SRI and more farmers cultivating rice under this production system would dramatically raise domestic production, and create favorable market conditions for producers and processors alike. More Liberian grain in the marketplace would allow domestic rice to be more competitive with imported grain, and ultimately would help decrease the reliance on imports, and alleviate the stress on the national budget.

3. **Encourage more small and medium-scale infrastructure investments for post-harvest aggregation centers and processing facilities.** Farmers in Liberia are severely limited in terms of where they can store and how they can process their rice. These limitations have ultimately capped domestic rice production as the prospect of post-harvest loss heavily influences cultivation decisions. Whether public or private sector investments are made, there is a real demand for small and medium-sized warehousing and milling facilities throughout the country. Using policy to create a suitable environment for investing in the value-chain can increase farmer access to adequate storage and processing facilities, and encourage more domestic rice production while generating non-farm employment. This will contribute to food security and economic activities for the whole of Liberia, and would be especially significant for rural communities and farming households, as individuals in these areas suffer the highest rates of hunger and poverty in the country.

4. **Expand the "Home-Grown School Feeding" Program.** Rice farmers in Nimba County that participated in this study attested to the benefits they experienced while acting as a

supplier in this school meal project. The HGSF social protection program offers a range of positive impacts for the country by connecting farmers with a guaranteed market before harvest, improving food and nutrition security in school children, and incentivizing school attendance for advanced educational outcomes. Unfortunately, a decline in this program was reported between 2015 and 2018, with beneficiaries dropping from 500,000 to 300,000 students, respectively (PAPD, 2018). In the past, this program has been implemented with large-scale farming cooperatives to procure sufficient rice supply for schools, but if grain could be sourced from farmer aggregation centers such as those discussed in the third recommendation (above) smallholders could easily participate in this program and help fill any gaps in supply through collective action. Investing more in this program would yield short-and long-term benefits for the economy and society, and encourage better health and educational outcomes for children – the nation's future.

5. **Establish other direct market linkages for rice farmers with public sector institutions.** Similar to the "Home-Grown School Feeding" Program, creating direct market linkages for rice farmers to supply other public sector institutions such as the national armed forces, police academy, universities, hospitals, even prisons can yield substantial benefits. One of the main challenges rice farmers faced in this study was in marketing their surplus grain. This barrier often led to post-harvest losses for farmers. An arrangement to supply public institutions, mediated by the government, can guarantee a market for domestic rice farmers and reduce the burden farmers face at harvest while fulfilling a consistent demand often supplied by imported rice. Imports have a tight grip on all aspects of the domestic rice market, and to make real progress toward rice self-sufficiency, government interventions are necessary to better support domestic producers. Moreover, this facilitation can send a

message of good governance to all Liberians and help build trust in the public sector by prioritizing the concerns of people over special interests.

6. **Make micro-loans and grant funding more accessible and inclusive for all farmers, farming associations, and youth organizations.** Farmers understand the issues they are facing better than anyone, and most farmers know the solutions to overcome these issues but lack the financial resources to do so. Increasing access to micro-finance and grant funding for all applicants regardless of age, asset ownership, land tenure, or farm size is critical for empowering these individuals and providing them with the tools necessary to take control of their lives – pillar one of the PAPD. This is especially important for youth in the country, who represent the largest cohort in the population and are among the most vulnerable to economic hardships and unemployment. Reducing these barriers to acquiring financial resources is another step toward building trust in the citizens of Liberia and will demonstrate an accountable and inclusive public sector – pillar four.
7. **Increase the number of commercial banks throughout the country to help stimulate agricultural production and processing.** There are far too few commercial banks across Liberia, which hinders private sector investment in agricultural production and processing activities. Increasing the number of commercial banks throughout the country would expand access to financial services for farmers, business people, and the general public, and help to encourage more entrepreneurship in small-and medium-sized enterprises. This type of private sector investment is needed to raise agricultural productivity and improve access to resources for the most vulnerable people. Particularly in Lofa County, known as one of the breadbaskets of the country, farmers expressed the need for more banks that offer agricultural loans to enable them to invest in themselves and their farming operations.

Lack of access to financial resources not only restricts farmers' ability to purchase tools, equipment, and production inputs, but it also limits the availability of dealers for these materials, forcing farmers to travel great distances to find what they need. This reduces the vast majority of farmers to subsistence or semi-subsistence production with only the wealthiest farmers able to mobilize the time and financial resources to seek and acquire productivity enhancing tools, equipment, and production inputs. To encourage investment and inspire innovation in domestic agricultural production and food processing, financial services must be available for all individuals across the country.

8. **Develop and incentivize alternatives to shifting (slash-and-burn) cultivation.** Liberia is home to 42% of the remaining Upper Guinea Forest (PAPD, 2018), and deforestation is threatening this rich ecosystem, as well as other forests in the country that are home to countless biodiversity. Upland rice grown with shifting cultivation practices contributes to this problem, and studies show this type of land-use change can have devastating effects on the sustainability of agricultural production. Moreover, the research discussed in this paper indicates that lowland rice cultivation in tandem with the SRI production system can drastically outperform upland rice systems. Eliminating slash-and-burn cultivation in Liberia will require a multi-phased approach that should include investments in education and incentives for conservation. This could be in the form of community-based strategies for land-use planning and management, forestry programs that reward land stewardship, and extension and rural development initiatives that work with famers to transition out of this cultivation practice. Integrating this recommendation with recommendation number two (above) could provide two-fold benefits by increasing rice production and mitigating

further deforestation. The intention here is not to punish farmers for traditional practices, but rather provide them with resources and capital to make informed decisions.

9. **Develop national marketing campaigns to encourage the consumption of Liberian rice.** The demand for domestic or *'country rice'* is quite low in local markets as compared to imported rice. This low demand creates difficulties for farmers and often dictates the amount of land used for growing rice. One simple strategy to increasing local demand is to educate consumers on the advantages of purchasing Liberian grown rice. Throughout the world, advertising is used to influence consumer behavior and to support the *'buy local'* movement. These advertisements tend to focus on the economic benefits and the multiplier effect derived from supporting local farmers and businesses. Funding a national marketing campaign could facilitate a change in consumer preferences in Liberia and inspire more rice farmers to increase their production to keep up with demand. Using a multi-media marketing campaign through radio, television, internet, billboards, and other forms of audio and visual advertisements would ensure a wide audience could be reached, even in the most remote areas. Some examples of marketing campaigns are to provide relevant statistics with regard to buying and consuming Liberian rice, or running advertisements that feature prominent athletes, celebrities, or politicians eating, enjoying, and promoting Liberian grown rice.

10. **Increase the number of public sector agricultural officers for technical capacity building and human development.** Throughout Liberia there is an expressed need for more field level extension officers in agriculture. The ratio of public extension officers to farmers is currently very low, limiting household and community access to the education programs and advisory services public extension is charged with providing. While the

consequences for Liberia’s agricultural production and rural quality of life are not documented in a comprehensive manner, numerous studies in other countries have confirmed the positive returns to investments in public sector extension (Evenson, 2001). District Agriculture Officers (DAOs) are responsible for covering large geographic areas and often have limited resources for transportation and farmer visitation. Across all six counties surveyed in this study, farmers expressed their sincere interest for more training opportunities and visitation from fields agents, and among those who received consistent advisory services the benefits were evident. Increasing the number of extension officers and funding for transportation, equipment, and training programs hold significant potential for helping farmers acquire the knowledge and skills necessary for resource-conserving approaches to improve rice productivity. Revitalizing Liberia’s public sector agricultural extension system will also provide new employment opportunities for recent graduates, young men and women alike, from tertiary agricultural education programs.

CHAPTER 6: PRACTICE

6.1 Summary

The Community of Hope Agriculture Project (CHAP) is the national champion for SRI in Liberia. Strongly committed to national food security, rural prosperity, and economic development, the organization helped enable this study in important ways. Key informant interviews with CHAP leadership and staff helped inform the study design and execution. The organization also provided invaluable assistance with transportation, organizing focus groups and interviews, and helping to identify study participants representing diverse perspectives on and levels of experience with the SRI method. The case study discussed in Chapter 4 of this paper utilized the extensive network of farmers across the country participating in CHAP-sponsored SRI training and advisory services. This network was vital to better understanding farmer experience with SRI in Liberia and enabled the assessment of farmer perceptions and attitudes toward the alternative practices in cultivation. Responses from study participants and data analysis revealed that farmers had technical training and advisory service needs that were frequently going unmet. Additionally, given the state of agricultural infrastructure in the country and the learning curve with this production system, having access to knowledgeable technicians was imperative for sustained SRI adoption. More training opportunities were often cited by farmers as a prerequisite for their successful application of SRI practices, and farmers expressed a strong desire for more on-farm visitation from extension agents and development practitioners to help them solve production and post-harvest challenges.

While the participants in this study were part of a broad network of rice farmers that receive advisory services from CHAP, the recommendations for development practitioners presented here are not exclusive to the organization, and should be considered by all development practitioners promoting SRI in Liberia. These recommendations were informed through personal discussions and interviews with farmers and aim to guide future training curricula and advisory services. Scaling this ecological production system in Liberia can transform domestic rice production and yield substantial positive outcomes for the economy and society, specifically regarding the national food deficit, hunger, unemployment, poverty, and human development. However, while potential benefits of this dynamic production system are significant, so are the barriers Liberian farmers experience with SRI implementation. Therefore, much more attention from policy makers and sustained engagement from development practitioners is needed to adequately support rice farmers and advance long-lasting impact for the current and future generations of Liberians.

6.2 Recommendations for Development Practitioners

1. **Expand training on water management and cropping calendars to avoid flooding.** In every county surveyed for this study, water control was the greatest challenge for farmers using SRI. Lacking permanent water infrastructure to store and control water throughout the year, farmers were left to their own ingenuity to create dams, center canals, peripheral canals, and drainage. Many farmers found this to be a significant limitation to the SRI method. Some noted that they had never gone to such lengths to battle the forces of the rainy season under traditional cultivation practices. Providing better training on how to create and manage locally appropriate water control infrastructure and protocols could alleviate these challenges and position farmers for greater success with SRI. In addition to developing stronger reservoirs and water storage with greater capacity, more training on cropping calendars is needed to educate farmers on the appropriate time to transplant rice. Because water control with SRI poses a major barrier for farmers in lowland cultivation, planting seedlings well ahead of heavy rains can mitigate flooding during the vegetative stage of crop growth. Water control is one of the fundamental components of the SRI

methodology, and this principle entails substantial change in farmer production practices, thus timely, practical, and sustained training is necessary to equip farmers with knowledge to overcome new challenges.

2. **Develop a practical training for improved soil management that focuses on organic fertilizer production and application.** Few study participants had received training on soil management and organic soil amendments. Multiple farmers noted that chemical fertilizers were prescribed to them when they first learned about SRI and they believed that NPK and Urea were central components of this production system. Though chemical fertilizer can be used in small amounts under SRI, the goal is to *reduce* the use of chemical fertilizer by creating healthy soil conditions through organic resources. Building fertile soil well-endowed in organic matter and beneficial soil biota is one of the foundational principles of SRI (Styger & Uphoff, 2016), yet nearly all the farmers in this study lacked this knowledge. Across the surveyed communities, organic resources were abundantly present but farmers were unaware of how to turn these raw materials into a suitable product for rice cultivation. Developing practical trainings for soil management, compost making, manure applications, and crop residue incorporation will help empower farmers with knowledge and skills for converting locally available resources into organic fertilizers. This training is imperative for Liberian farmers moving forward as the rapidly increasing price of chemical fertilizer puts it out of reach for many small farmers. In addition, the overuse of commercial inputs is contributing to soil degradation and environmental pollution.

3. **Incorporate more training in the use of weeders.** Weeding was the third most labor-intensive practice associated with SRI reported by participants in this study, and of the 125 farmers surveyed 121 of them stated they used hand weeding in some combination of weed

control. Greater attention in SRI training is needed to build farmer capacity for weed control using mechanical implements. Tools like hoes and weeders can help reduce the labor exerted in the field and provide multiple soil benefits that lead to improved plant growth and development. The “Garden Weasel” was used by 33 farmers and almost everyone in this study had access to hoes or other mechanical implements, however, few understood why mechanical weeding was the preferred weed control method under SRI. One of the main criticisms of using the mechanical weeder was that it only worked when the grass or weeds were small, and as weeds grew bigger the tool was less effective. This is a perfect example of why more rigorous training on weeding is necessary, as allowing grasses and weeds to grow increases the competition with rice plants for space, nutrients, light, and water. Frequent weeding using a mechanical implement can help limit plant competition and aerate the soil, and studies have shown increased weeding sessions will increase rice yields and farmer income. It is recommended to use a mechanical weeder three to four times per season under SRI, whereas most farmers in this study would weed by hand just once or twice per season. Practitioners can also play a role in improving access to weeders that have been tested and deemed useful by farmers, and help identify local metal fabricators who can replicate and/or adapt tools popularized elsewhere.

4. **Encourage farmer experimentation.** A common trend revealed in farmer responses during discussions and interviews was the lack of experimentation with different practices and limited adaptation of the SRI method. Most participants followed the practices exactly as they learned them, and many would abandon the production system if they were unable to follow these practices. However, one of the unique aspects of this production system is that farmers are not confined to a rigid set of instructions. Practitioners should provide a

basket of recommended SRI practices to farmers and encourage them to experiment with the idea not all will be applicable to every farmer. The four principles discussed in Chapter 2 are the only fixed criteria of this system and farmers should be encouraged to find the practices that work best for them in their specific farming context. Reorienting training with a focus on the underlying principles of SRI, and engaging farmers in brainstorming and testing locally-appropriate practices consistent with those principles may improve uptake of SRI, and stimulate a regional culture of experimentation and innovation with benefits well beyond rice farming.

5. **Establish community-based SRI technicians using lead farmers in every community.** Data analysis indicated that SRI adopters had a higher prevalence of knowledgeable 'lead farmers' in their community compared to dis-adopters. Lead farmers share the knowledge they possess with others in the community and often provide impromptu advisory services in the absence of formal extension agents. Creating a community-based extension model that utilizes lead farmers can help find solutions to challenges associated with SRI dis-adoption. Well-prepared and supported lead farmers understand local issues, often enjoy high levels of trust and respect among their neighbors, and can help build and leverage the knowledge and networks of public extension and other development practitioners. In comparison to an outside extension agent coming to the community and establishing a demonstration plot for training and then leaving, when a lead farmer attends a training and is tasked with returning to their community to establish a demonstration, there is a greater understanding of the SRI principles and practices and more enthusiasm for this production system among farmers. Investing in more lead farmer training in conjunction with

demonstrations plots can help overcome important barriers to successful and sustained transition to resource-conserving and yield-enhancing practices.

6. **Increase lead farmer training opportunities to continue engagement and investment in community-based technician model.** Building off recommendation five (above), lead farmers need continued opportunities to participate in training programs – *at least once or twice per year*. SRI is much different than traditional rice management, bringing new questions and challenges at all stages of testing and adoption. Backstopping farmer SRI testing with well-prepared ‘lead farmers’ and timely training will help all farmers better understand and successfully implement this production system. Over time, user input and iteration in the training curricula as well as farmer experimentation protocols will bring adaptations that fit the special biophysical and socio-economic circumstance of the locale. It is imperative to value these lead farmers as key catalysts for knowledge exchange and innovation and to therefore invest in their development and capacity. Regular opportunities for training and modest financial compensation are recommended to enhance their ability to serve in the community and bolster their commitment to the agroecological principles for improved rice productivity.

7. **Conduct annual community meetings to visit demonstration plots and learn from farmer experiences.** Throughout this study, farmers expressed their desire for more visits from extension agents and development practitioners. In many cases, farmers claimed they had not received any visitors on their farm in years. On more than one occasion, farmers stated they gave up on SRI because they felt extension personnel gave up on them, and had they been encouraged to continue through visitation and additional support they would still be practicing. It is clear that SRI has been promoted with a wide network of farmers

throughout the country but much more support needs to be made available to these farmers beyond the initial training. Holding annual exchange visits for farmers in the network and recognizing their work can inspire greater openness to new and sometimes unconventional ideas and promote local innovation. Annual visits would also create a two-way learning process by enabling field agents and practitioners to see the achievements and challenges first-hand, providing opportunities for the development of new training curricula and new ideas for broader on-farm testing.

8. **Institute demand-driven extension and advisory services to fill the gaps pertaining to the specific challenges.** While improving training protocol for farmers and establishing lead farmers as community-based technicians can advance knowledge of SRI and increase adoption of this production system, some challenges farmers experience may still be too difficult to overcome and thus will require more precise technical knowledge. Providing demand-driven extension and advisory services can help address these more complex or pervasive problems farmers face. This extension model has been used elsewhere in the world, and typically serves larger farmers or cooperatives seeking assistance with issues such as irrigation design, new cultivation techniques, or marketing strategies, but it is rapidly being used with small farmers. One innovative way to deliver this kind of service would be to enlist the help of a champion SRI farmer who possesses the desired skills being requested. For a small fee, paid by the requesting individual or community, this champion farmer/technician would be dispatched to provide support in the area they are seeking assistance with. This approach can stimulate innovation through farmer-to-farmer engagement and can create additional income for SRI farmers by utilizing the skills they have acquired.

9. **Develop better training for post-harvest management and marketing.** The SRI method generated yield increases for all farmers in this study and roughly 85% of these farmers

said their yields surpassed household consumption needs. This presented new challenges in storing, processing, and marketing surplus grain; and unfortunately, due to insufficient post-harvest management strategies it led to higher rates of spoilage. Although SRI training tends to focus on capacity building and skill development for cultivation practices, more training must be provided on marketing and post-harvest management to reduce losses and increase income generating potential. Taking groups of farmers to nearby markets, talking with sellers and buyers, and conducting a marketplace assessment would enable farmers to better understand market demands. Furthermore, simple training with regard to processing, grading, sorting, packaging, and selling can help rice farmers be more competitive with imported rice in the market. There are various factors that influence consumer demand and educating farmers on these factors can yield a substantial impact for income generation and farmer profitability.

10. **Improve training on land preparation, equipment use, and equipment maintenance.** Reducing the drudgery with SRI is critical to getting farmers to embrace this production system. 80% of the participants in this study perceived SRI to be more labor-intensive than traditional cultivation practices, and the number one activity that demanded more labor was land preparation. A minority of the participants surveyed had access to a power tiller, which substantially reduced the labor demand for land preparation; however, more education on the use and maintenance of this equipment is needed to ensure it stays in working condition. Power tillers enable farmers to brush and till the land with ease and reduce land preparation time dramatically, but without thorough training on this equipment it can be damaged easily, as was the case with multiple farmers in Lofa County. Therefore, more training must be devoted on the proper ways to use a power tiller as well as the essential maintenance to

keep this piece of equipment functioning. Investing in technicians that can travel to farmers and communities and provide this kind of education and training could prove helpful and work in harmony with recommendation nine (above).

CONCLUSION

The System of Rice Intensification (SRI) is a dynamic methodology for rice cultivation that builds on ecological principles for sustainable and resilient agriculture. This production system utilizes a comprehensive set of agronomic practices that enhance crop and capital productivity, and it has demonstrated substantial yield, resource conservation, cost, and resilience benefits for smallholder farmers. SRI holds potential for significantly increasing rice production in Liberia, and doing so using practices that save water and reduce external inputs. Liberia's climate, land characteristics, and water resources are favorable for lowland rice cultivation with SRI, and the grain is already among the most popular crops grown by farming households throughout the country. However, to maintain farmer interest in this production system, additional support from policy makers and development practitioners is needed. Some Liberian farmers have taken up this production system with relative ease and many describe it as a superior method for growing rice, but the lack of basic infrastructure and technical assistance, specifically with regard to water control and post-harvest storage and milling, has limited wide-spread adoption of SRI.

For decades Liberia has depended on imported rice for its national consumption, but the procurement of this grain will become increasingly difficult as demand for rice soars on the world market while climate change continues to threaten production and trade. The global population is not expected to peak until 2060, and with much of the growth taking place in sub-Saharan Africa (Barrett et al., 2020) – a region embattled by food deficits – competition for imported rice is likely to intensify moving forward. Therefore, high potential agri-food innovations such as the System of Rice Intensification hold promise for mitigating food shortages and related political instability. Public and private sector investments in infrastructure are essential to better support domestic rice producers while policy and practice can help facilitate the progress toward rice self-sufficiency in Liberia, and ultimately contribute to the structural transformation for economic development.

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APPENDIX

A: Focus Group Discussion Questionnaire

1. When and how did you learn about SRI?

    a. Can I see a show of hands, how many attended an in-person training (formal) and how many learned from another farmer (informal)?

2. What made you want to try SRI on your farm?

3. Have you seen increases in yield since switching to SRI?

    a. Yields before and after?

4. How is SRI different from what you were doing before?

5. Have you tried experimenting with different SRI practices?

    a. Which ones?

6. Which SRI practices do you believe result in more yields?

    a. I have heard from other farmers that ____________ is a common practice. Is it possible to try this practice here?

    b. If no, why not?

7. What are the biggest challenges with SRI?

8. How do you control weeds?

    a. How many times in one rice season do you weed?

9. Why do you think some farmers adopt SRI and other choose not to?

10. How are SRI farmers and conventional rice farmers different from each other?

11. What is the most important source of new agricultural ideas and information?
    a. Ex. Family members, neighbors, extension agents, NGOs, input suppliers, radio, mobile phone, internet, etc.

12. Would receiving farming information by mobile phone be helpful?

    a. Yes, how?

    b. No, why?

13. In what ways do you think trainings about SRI can be improved?

B. Semi-Structured Interview Questionnaire

General Farm Information

1. How long have you been farming rice in this area?

    a. Besides rice, do you raise any livestock/animals or other crops?

2. How many acres (units) of land do you farm?

    a. How much of it is in rice (rough percentage)?

3. What time of the year do the rains come? When do you plant rice?

    a. How many times do you harvest rice in one year?

4. What do you do with rice harvested?
    a. Eating/household consumption
    b. Sale/market
    c. Both

5. Is farming your only source of income? Other income sources?

6. Can you tell me about the labor/workforce on your farm?

    a. In general, is it family/household members, or do you hire additional labor?

7. How would you describe the soil quality on your farm, is it fertile soil (good or bad)?

    a. Have you noticed if the soil is changing over time?

    b. Have you tested your soil? How?

    c. Do you use any soil amendments/fertilizers? If yes, what kind?

System of Rice Intensification (SRI)

8. When and how did you learn about SRI?

    a. Did you attend a training?

9. What made you want to try SRI on your farm?

    a. Have you seen increases in your rice yield since switching to SRI?

        i. What was your average harvest yield before SRI?

        ii. What is your average harvest yield after SRI?

    b. How long have you been growing rice with SRI?

10. How many seeds you have sown to plant with SRI (kg)?

11. How is SRI different from what you were doing before?

12. What practices do you use when doing SRI?

    a. Have you tried different SRI practices?

13. In your experience, are there any practices that result in more yields?

    a. I have heard from other farmers that _____________ practice is common in some places. Have you tried this on your farm?

    b. Is it possible to try this here? Why, or why not?

14. What are the biggest challenges with SRI for you?

15. What farming tools are you using (weeder, hoe, cutlass, etc.)?

    a. How do you control weeds in your SRI fields?

b. How many times do you weed in one rice season?

16. How do you manage water in your SRI fields?

    a. Can you control water during the vegetative (early) phase?

    b. Can you control water during the reproductive (late) phase?

17. Have you shared what you know about SRI with other people?
    a. Ex. Family members, friends, neighbors, or others.

    b. Have they tried SRI in their fields?

    c. Do they still practice SRI?

<u>Social Capital and Networks</u>

18. What is the most important source of new agricultural ideas and information for you?

19. Besides CHAP, are there other agricultural organizations working in this area? Who?

    a. How often do you receive advice from this/these organization(s)?

20. Do government extension agents provide you with agricultural services/advice?

    a. Do government extension agents live in or around this area?

    b. How often do you receive agricultural advice from government extension?

21. Do you ever work together (collectively) with other farmers in agricultural activities?
    a. Ex. Land preparation, transplanting, weeding, harvesting, etc.?

    b. What kind of farmer cooperation is most common?

22. Are there any organized farmer groups, associations, or cooperatives in this area?

a. What kind of services do they provide to farmers?

b. Is there a fee to join these groups?

23. Are there any ‘lead farmers’ that serve as a resource for other farmers in this area?

24. Do you receive agricultural information or training materials through mobile phone services?

    a. Would getting information about farming sent to your mobile phone be helpful?

Final Question

25. What ways do you think SRI training can be improved?