The Effectiveness of Systems of Rice Intensification (SRI) in Fostering Socio-Economic Development in Rural Cambodia

Master's Thesis

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Executive Summary

This review explores the developmental impact of Systems of Rice Intensification (SRI), on rural households located in the Takeo province of Cambodia. SRI is a sustainable means of rice production, that has been heavily promoted in the country by the government, and a multitude of NGOs, since the early 2000s. To explore these impacts, this research incorporates a livelihoods framework in conjunction with a sustainability framework. In turn, the impact of SRI is evaluated in terms of its influence on the livelihood outcomes of its implementers. A more comprehensive evaluation is then achieved, by reviewing the livelihood outcomes within a set of sustainability criteria. This research has found, that there are some cases where SRI has led to substantial livelihood improvements, that meet the sustainability criteria. Despite this, it has also been found that SRI implementation is on the decline in the region. The reasons for this decline become apparent, as the developmental impacts are assessed through the respective frameworks.

Acknowledgments

Exploring this topic has been a genuine learning experience. The culmination of this report would not have come about without the support of some wonderful people. I wish to thank my supervisor Guus van Westen; for helping me focus my objectives, and for providing insightful feedback to concerns that I had along the way. Then, I would like to thank Hami Zanne; for the many hours spent aiding me with translations, and his persistent dedication to keep venturing out in search of respondents. I wish to thank my parents, for their continued encouragement and support. Lastly, I wish to thank all the respondents who took the time to share their stories with me. Among them, I wish to give special thanks to Ms. Lay Guecsim and Mr. Ros Mao; whos' beacon of inspiration is invaluable.

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Abbreviations

CEDAC – *Center for Studies and Development of Cambodian Agriculture*
FAO – *Food and Agriculture Organization*
GHG – *Greenhouse Gasses*
GTZ – *German Technical Cooperation Agency*
KHR – *Cambodian Riels*
MAFF – *Ministry of Agriculture, Forestry, and Fisheries*
NGO – *Non-Governmental Organization*
NSDP – *National Strategic Development Plan*
OECD – *Organisation for Economic Co-operation and Development*
SRI – *Systems of Rice Intensification*
UNCED – *The United Nations Conference on Environment and Development*
USD – *United States Dollars*

Introduction

Problem Statement

Rural development often remains a priority area of attention for developing countries. This holds true for Cambodia; which despite having experienced substantial development over the past two decades, still faces significant poverty and issues pertaining to food insecurity among its rural population. With most of those impoverished being dependant on agricultural livelihoods, the challenges facing rural development are exasperated by an increasing vulnerability resulting from climate change. For this reason, it is imperative that development in the region account not only for socio-economic factors, but also environmental factors in a holistic fashion. Furthermore, if these development initiatives are to be lasting and resilient, they must account for the sustainability of these three dimensions.

In response to the challenges facing the rural sector in Cambodia; agro-ecological and other sustainable agricultural practices have become a popular means to promote agricultural development, whilst strengthening resilience to climate variability. Consequently, in Cambodia the agricultural practice of *Systems of Rice Intensification (SRI)* became increasingly popular over the past two decades. SRI has been promoted as a promising solution to Cambodia's struggling rice industry. It is an organic method, that is said to boost yields, whilst reducing stress levels on irrigation water, and other production inputs. Being a practice that is designed for an industry that not only serves a significant portion of the impoverished rural community, but also the broader Cambodian economy; SRI appears to be a viable means to foster socio-economic and environmental development in Cambodia. There is, however, debate amongst the scientific community regarding the actual effectiveness of SRI as an agricultural practice. Furthermore, it is argued that the implementation of SRI may lead to unintended social and economic disparities. In addition, there remains ambiguity regarding its capacity to promote socio-economic, and environmental, development in the face of contextual systemic and environmental barriers.

In turn, this research aims to explore the following question:

Research Question

To what extent is the implementation of Systems of Rice Intensification (SRI) in Cambodia effective in fostering rural livelihood development; that accounts for holistic social, economic, and environmental sustainability?

Research Objectives

The objective of this research is to review the way SRI impacts the development of rural Cambodia. This is done in the context of the social, economic, and environmental spheres. To do this, the review is conducted on the micro-household scale, whilst holding consideration of the macro-contextual scale. In turn, for analysis, this review implements the livelihood framework; which accounts for the relationship between a household's livelihood assets/ strategies, and the broader transforming structures and vulnerability context.

Consequently, the objective of this review, is to:

- explore whether SRI works as a practice;
- establish what the (social, economic, environmental) development implications are of SRI;
- understand potential trade-offs between the social, economic, and environmental effects of SRI;
- explore the potential unintended social and/or economic effects that may result from SRI implementation;
- define the influence of potential contextual barriers that may hinder the development potential of SRI.

This review intends to contribute to the existing debate regarding the effectiveness of SRI as a practice for rural development; and address the contention surrounding its socio-economic consequences. The goal is to provide an in-depth understanding of the nature in which the implementation of SRI impacts the livelihoods of rural Cambodian households. Consequently, this review explores whether SRI can deliver social, economic, and environmental development in a unified manner; or whether these dimensions come at odds.

Contextual Overview

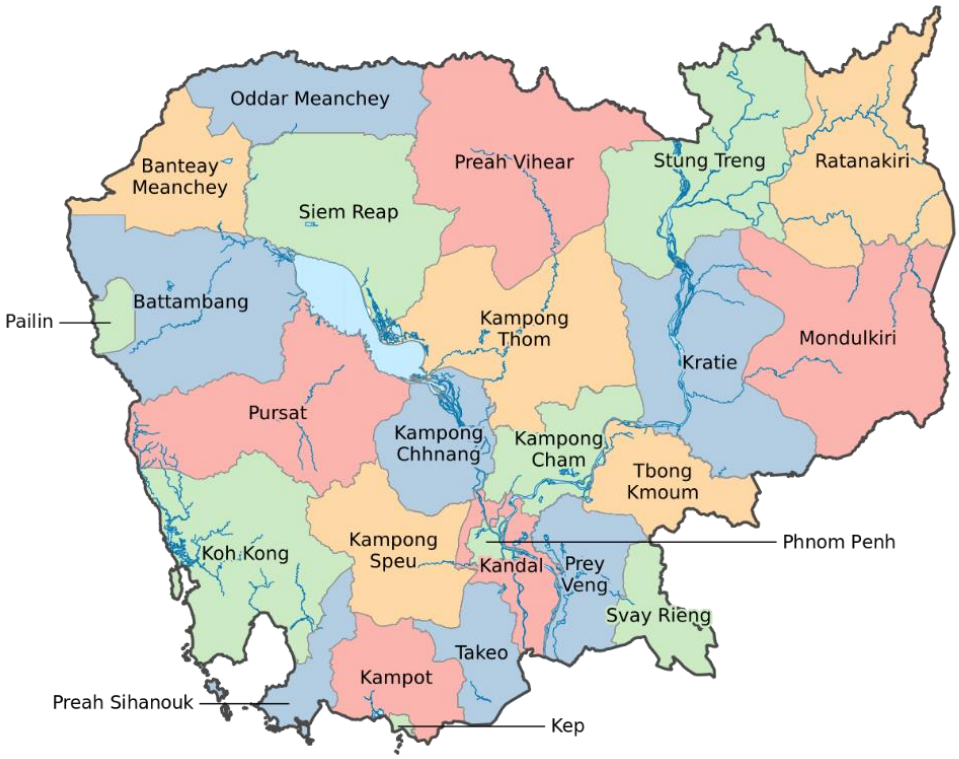


Figure 1 – Map of Cambodia (Wikipedia, n.d.).

Cambodia's Development Status

Cambodia, located in South-East Asia, is a country that has experienced significant development over the past two decades. The country has achieved macro-economic stability and growth through its efforts to become more integrated in the region (The World Bank, 2016). The macro-economic development in Cambodia, has primarily been driven by its garment, construction, and service sectors[1] (The World Bank, 2016). Despite this apparent shift towards a manufacturing and service based economy, the agricultural sector still plays a significant role. Not only did the agricultural sector contribute a 28.3% of the GDP in 2014, but in 2004 it employed 52% of the male population and 56% of the female population (The World Bank, n.d.).

With an annual GDP growth rate of 7.04% in 2015, and an average annual growth rate of 7.6% between 1995 and 2015, Cambodia has achieved substantial reductions in its poverty (The World Bank, n.d.; Food and Agriculture Policy Decision Analysis, 2014). Despite these improvements, poverty rates remain significant, as 13.5% of the population were below the national poverty line in 2014; and in 2012, 6.2% of the population were in extreme poverty[2] (Asian Development Bank, 2016). The poorest demographic is comprised of*: rural households with access to small areas of land with no other productive assets; landless rural individuals; women, and households headed by women that contain many dependents; and indigenous minority ethnic groups* (International Fund for Agricultural Development, 2014). In turn, Cambodia still holds the status of a low-income country, and has maintained its

[1] The industry and service sectors, contributed 27.1% and 42.4% of the GDP respectively in 2014 (The World Bank, n.d.).

[2] Below the $1.90 purchase power parity (PPP) a day.

classification under the United Nations (UN) as being one of *the least developed countries* (Food and Agriculture Policy Decision Analysis, 2014; The World Bank, n.d. a).

Concerns have been raised, that Cambodia's economic growth has not benefited members of the population equally; and that disparities manifest with regards to unequal access to infrastructure, and productive assets (Asian Development Bank, 2012). This is made apparent by the high levels of income inequality[3] (Food and Agriculture Policy Decision Analysis, 2014). These disparities have affected the rural population disproportionately; as approximately 90% of the poor live in rural areas (The World Bank, 2016). The high levels of poverty and income inequality are drivers that have, in part, contributed to food insecurity in Cambodia.

Between 2014 and 2016, 14.2% of Cambodia's population were classified as achieving below the minimum level of dietary energy consumption (Asian Development Bank, 2016). Cambodia received a score of 21.7 on the Global Hunger Index in 2016; thereby classifying it as experiencing *serious hunger* levels (Grebmer, Bernstein, Prasai, Amin, & Yohannes, 2016). Furthermore, in 2010, 28% of children were undernourished and facing chronic malnutrition and micronutrient deficiencies (Food Security Portal, n.d.). In turn, Cambodia is considered to experience high levels of essential vitamin and nutrient deficiencies (World Food Program, 2014).

These levels of malnutrition, can be associated with the fact that the Cambodian diet is dominated by rice and other cereal grains. In 2009, it was reported that cereals comprised 71% of the Cambodian diet (Food and Agriculture Organization, 2014). This can primarily be attributed to the fact that the Cambodian agricultural industry is dominated by rice production (Mund, 2011). Furthermore, food insecurity and malnutrition in Cambodia is also a consequence of the relationship between commodity price volatility in an uncertain economic climate, and rural poverty and income inequality (Organization for Economic Co-operation and Development, 2014).

Evidently, with the consideration that poverty is concentrated among the rural demographic; addressing issues pertaining to rural development and food insecurity remain priority developmental concerns for Cambodia. These issues are intrinsically interconnected, and cannot be addressed separately; especially with the consideration that Cambodia's rural population are highly dependent on agricultural livelihoods[4].

As mentioned, the agricultural industry is dominated by rice production[5] (Mund, 2011). The sector, however, is vulnerable to drought and flooding that result from weather variability (Phirun, Sreymom, Dara, and Chhuong, 2014). In addition, the sector faces several constraints that hinder its development. Many constraints manifest in structural forms; such as supply chain inefficiencies, poor milling and transportation infrastructure, and poor access to land and financial capital (Asian Development Bank, 2012; Mund, 2011). The core issue facing the sector, however, is that agricultural productivity is poor and narrowly based on a few crops; whilst water resources remain underperforming and underdeveloped (Asian Development Bank, 2012). Reportedly, the average rice yields in Cambodia are amongst the lowest in the region (Yu & Fan, 2011); which is a factor that ultimately undermines Cambodia's ability to develop its rice export base. If Cambodia could increase its yield potential to match Vietnam's average yield rate, it is reported that this could bring in an additional $35 million per year to the income of farmers (Yu & Fan, 2011). An increase in productivity, in turn, could support regular rice exports and bring a significant number of rural households out of poverty.

[3] In 2012, the GINI Index was reported to be 30.76 (The World Bank, n.d.).

[4] The sector is comprised of land-owning households, self-employed agricultural workers, and unpaid family workers who operate on their own subsistence production system (Food and Agriculture Organization, 2010).

[5] It is estimated that 86% of rice produced is either irrigated or rain-fed lowland rice; whilst only 8% is dry-season rice (Mund, 2011).

Systems of Rice Intensification in Cambodia

In response to issues pertaining to productivity, water management, and climate vulnerability; the promotion of the sustainable practice of *Systems of Rice Intensification* (SRI) has become prominent in Cambodia (Ly, Stoumann, Bech, Rutz, & de Neergaard, 2012). It has been promoted as a promising solution that results in socio-economic development; whilst promoting social, economic, and environmental sustainability. This is achieved, because it is argued that SRI has the potential to increase yields by more than 60%[6]; whilst reducing water use and greenhouse gas (GHG) emissions (Gathorne-Hardy, Reddy, Venkatanarayana, & Harriss-White, 2016).

SRI was first introduced in Cambodia in 1999 by Dr. Y. S. Koma; the director of the Center for Studies and Development of Cambodian Agriculture (CEDAC) (Cornell University, n.d.). By 2000, there were 28 participating households in the country, and reports of their success led the Cambodian government to officially endorse the method by 2005 (Cornell University, n.d.). Consequently, SRI was incorporated in the National Strategic Development Plan (NSDP) between 2006 and 2013 (Cornell University, n.d.). Since its initial introduction, at least 47 non-governmental organizations (NGOs) and development projects have promoted SRI in varying regions of Cambodia (Cornell University, n.d.). The most significant initiative, was established by the Ministry of Agriculture, Forestry, and Fisheries (MAFF); with the assistance of CEDAC, the German Technical Cooperation Agency (GTZ), Oxfam America, the Food and Agriculture Agency (FAO), and HEKS (a Swiss aid organization) (Cornell University, n.d.). This initiative consisted of the establishment of a 'national SRI secretariat'; which coordinated and assisted SRI activities in Cambodia[7] (Cornell University, n.d.). The effect of this initiative, and the overall NGO involvement, were significant; as it is estimated by CECAC, that there were approximately 100,000 households implementing SRI in Cambodia by 2011 (Cornell University, n.d.). Although the government played an important role in promoting SRI, the efforts made by NGOs are significant. This point is extenuated by the fact that by 2012, it is reported that CEDAC alone was directly supporting 140,000 households with the education and implementation of SRI (Cornell University, n.d.).

[6] It is reported that the SRI can provide yields of 5 – 15 tons/ha (Ly et al., 2012).

[7] The secretariat, however, has become less active between 2010 and 2013 (Cornell University, n.d.).

SRI is a method of irrigated rice production, that entails careful plant, soil, water, and nutrient management practices. It was developed by Fr. Henri de Laulanie in Madagascar, with the aim is to induce larger better functioning root systems; and promote more abundant, active, and diverse soil biota communities that are associated with those root systems (Uphoff, 2006). In turn, SRI incorporates five processes:

- 1. First, the recommended practice starts with the use of transplanted seedlings. To do this, young seedlings are grown in a dedicated 'nursery' plot, and are then transplanted into the cultivation field(s) early in the season. The transplanting occurs when the seedlings are still young (8-12 days old), and only the strongest plants are selected. Although this is the recommended means of cultivation, it is reported that direct-seeding also leads to beneficial results.
- 2. Following the recommended starting method, transplants are planted so that each mound consists of one plant (rather than containing clumps of 3-6 plants). Transplanting is to be done quickly (within 15-30 minutes from the removal from nursery), gently (to not damage the roots), and placed shallow in the ground (1-2cm deep). Providing such careful handling is made possible due to the severe reduction of plants that are grown in an area.
- 3. A crucial element to the system, is that the mounds and plants be placed with wide spacing in a grid-pattern. The initial recommendation is that there is spacing of 25x25cm. This spacing is intended to facilitate weeding and maximize nutrient uptake per plant.
- 4. Next, another crucial factor is that the rice paddies are irrigated intermittently, so that the soil is kept moist and under mostly aerobic conditions. This is contrary to the conventional method of continuous flooding, where paddies are kept under anaerobic and hypoxic conditions. Due to the spacing and intermittent flooding, it is to be expected that more weeding will be required. In turn, it is recommended that a 'rotating hoe' be used. The use of this would aerate the soil, whilst churning the weeds back onto the soil to decompose and recycle their nutrients.
- 5. Lastly, although not an essential component, it is highly recommended that organic compost be used over synthetic chemical fertilizer. The use of this has repeatedly been reported to provide better results; although it is possible to achieve yield increases without compost.
    - (Uphoff, 2006; Gathorne-Hardy et al., 2016).

A noticeable difference between SRI and conventional methods of rice production is the use of water. While conventional practices will typically grow rice under continuous flooding, SRI practices only intermediate flooding. It is argued that this leads to better agronomic and economic results (Uphoff, 2006). Keeping the soil under aerobic conditions promotes the development of healthy root systems that would otherwise deteriorate under flooded conditions (Uphoff, 2006). Furthermore, it promotes the development of active communities of soil organisms. These +communities of soil organisms, in turn, provide a number of ecological services that promote the growth performance of the rice crop (Uphoff, 2006). These ecological services include:

- Biological nitrogen fixation;
- Nitrogen cycling by nematodes and protozoa;
- Greater uptake of nutrients and water by mycorrhizal fungi; which also provide resistance to various stresses;
- Phosphorus cycling by microorganisms;
- Plant growth promotion due to: induced systemic resistance; production of phytohormones; and protection against pathogens.
    - (Uphoff, 2006).

In addition to being beneficial for the soil biology, the use of intermittent flooding in combination with the use of lower than conventional number of plants, also results in a reduction in the need for irrigation water by 25-50% (Ly et al., 2012; Uphoff, 2006). This, in turn, benefits not only the farmer, but also the environment. Furthermore, it is argued that SRI can reduce the seed requirement by 80-90% (Ly et al., 2012). In addition, other factors such as the reduction in fertilizer expenses, further reduce production costs. It is argued that these reduction is production cost, can potentially increase after-cost returns by over 400%/ha (Gathorne-Hardy et al., 2016). It is evident why this method of production appears to be an appropriate response to the development of rural agricultural households. It is in turn promoted as a promising solution; because it provides both socio-economic benefits (due to the higher yield with lower costs), and environmental benefits (reduction in water stress and promotion of healthy soil biology).

There is contention, however, with regards to the effectiveness of SRI as a practice, and its development implications. It has been argued that SRI does not intrinsically improve yields, and that contrary claims are consequence of measurement errors in prior studies (Sheehy, Peng, Dobermann, Mitchell, Ferrer, Yang, Zou, Zhong, & Huang, 2004; Mcdonald, Hobbs, & Riha, 2006). In addition, although there are apparent benefits from SRI on water usage, it is also argued that this strict management of water also places the crops at a higher risk of failure (Dobermann, 2004). It is also argued, that for the effective management of water to take place under SRI, adequate irrigation infrastructure needs to be in place to mediate this (Uphoff, 2006). The scale of such projects shifts the dependency of their execution onto the government or development agencies (Uphoff, 2006). This, in turn, may prove to be a contextual barrier that may hinder the performance of SRI implementation. Furthermore, whilst SRI is said to reduce the need for certain inputs (such as water and fertilizer), it is also considered to be more labor intensive (Uphoff, 2006; Uphoff, 2007; Dill, Deichert, & Thu, 2013). This, in turn, is a factor[8] that limits the capacity for SRI to be implemented on an intensive scale on land that exceeds 1ha (Tsujimoto, Horie, Randriamihary, Shiraiwa, & Homma, 2009). In addition, debate has been raised as to the effects of SRI implementation on the agricultural labor demographic. Whilst it is argued that SRI labor demands could provide poverty reducing employment, contrary studies have found that SRI implementation led to decreasing labor demand, resulting from labor efficiencies (Uphoff, 2006; Gathorne-Hardy et al., 2016). It is argued that this decrease in employment disproportionately affects female landless labors, who are the most marginal members of society (Gathorne-Hardy et al., 2016).

Thus, it is apparent that although SRI is promoted as a promising means of development, there is enough debate in the scientific community to substantiate uncertainty regarding its social, economic, and environmental implications. In turn, this review aims to analyze whether SRI is effective in delivering sustainable development.

[8] Additional factors include: the high required levels of organic resources; and difficulties in managing irrigation water (Tsujimoto, Horie, Randriamihary, Shiraiwa, & Homma, 2009).

Theoretical Framework

Framework Overview

To analyse the developmental impact of SRI, this review utilizes a combination of frameworks. The impact is ultimately assessed in the scope of household's livelihoods in rural Cambodia. Thus, the relationship between SRI and livelihood outcomes is reviewed. This framework is of merit, as it accounts for the broader contextual influence, rather than simply looking at the direct livelihood impact of SRI in an isolated fashion. To achieve a more holistic perspective, the livelihood outcomes are assessed through a sustainability framework. This framework acts as an appropriate extension to the livelihood impact review; as it accounts for the broader impact within the social, economic, and environmental dimensions.

Additionally, to gain a deeper understanding of the heterogeneous effects of SRI among the rural population, the social dimension of the sustainability framework is further extended to incorporate elements of food security, and gender dynamic, frameworks. Food security elements have been included in the review, since this remains a prime area of concern among the developmental status of rural Cambodia. Further, gender components have been included, due to the consideration that women, and female-headed households, are among those facing the highest levels of disparity and poverty in the country.

The culmination of these frameworks, provide an effective tool to review the varying dynamics between SRI and the components that comprise rural livelihoods. Further, it provides an effective tool to review the social, economic, and environmental development implications. This in turn enables careful review of the benefits and vices of SRI; whilst holding contextual considerations. This enables a dynamic perspective that analyses potential trade-offs, and unintended effects; whilst holding key considerations such as gender dynamics and the state of food security.

The Sustainable Livelihoods Framework

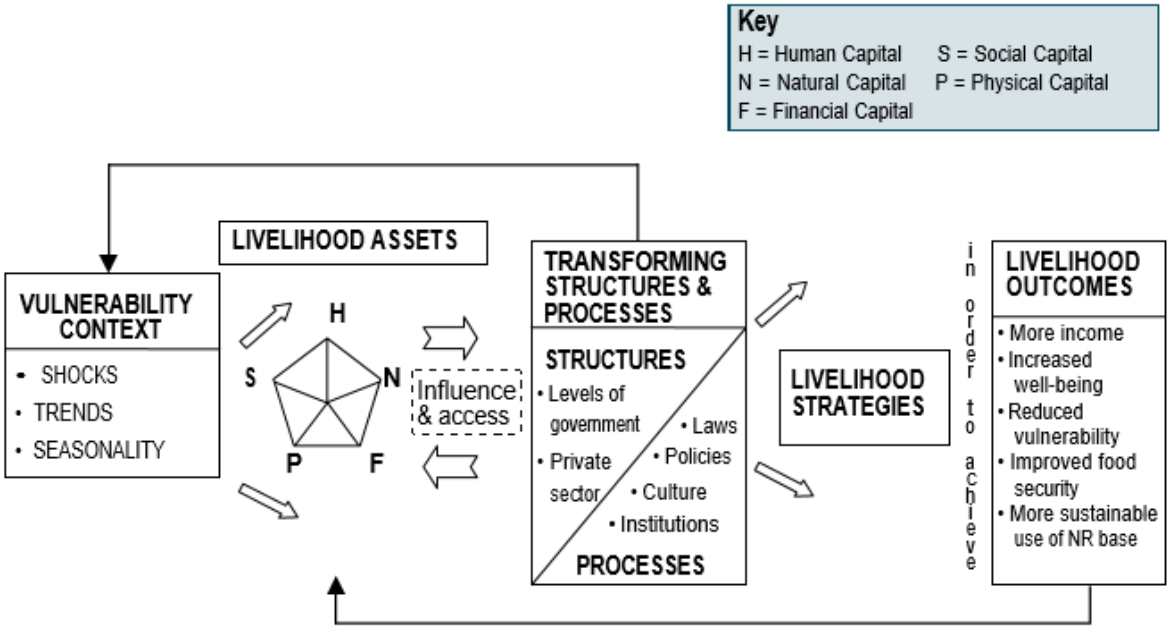


Figure 2 – Sustainable Livelihoods Framework (Department of International Development, 1999).

To understand how SRI impacts the rural community, the *Sustainable Livelihoods* framework is utilized; as it provides a means of reviewing the localized socio-economic and environmental impact. The *Sustainable Livelihoods Framework,* provides an effective means to evaluate the factors (and the relationships between them) that affect livelihoods (Berti et al., 2003). The framework provides a people-centered analysis, and encourages a broad systematic view of the variables that affect rural livelihoods and poverty (Krantz, 2001). It operates by reviewing how a household's livelihood outcomes are affected by: the vulnerability context in which they exist; the assets they possess; the strategies they engage; and the structures and processes through which they operate (Krantz, 2001). The framework not only analyzes how these variables impact livelihood outcomes, but also how these variables impact each other (Department of International Development, 1999). The variables are outlined as follows:

- The vulnerability context, frames the external environment in which people live. It does so by reviewing vulnerability in the context of *trends, shocks,* and *seasonality* in the external environment.
- The framework emphasises five forms of capital that comprise the assets on which livelihoods are established. These are divided into: *natural, physical, social, human, and financial capital*. An overview of the types of capital is presented in *Table 1*.
- Transforming structures and processes, are the institutions, organizations, legislation, and policies that influence and shape livelihoods. These variables determine the: access to capital; terms of exchange between capital, and returns of a livelihood strategy.
- Livelihood strategies refer to the range and combination of choices and activities that people undertake to achieve their livelihoods.
- Livelihood outcomes, in turn, refer to the resulting outcome of livelihood strategy efforts.
    - (Department of International Development, 1999).

Type	Description
Natural Capital	*The natural resource stocks that are utilized for livelihoods (Such as: land, forest, water)*
Physical Capital	*The infrastructure and producer goods needed for livelihoods (Such as: roads, telecommunicaton lines, shelter and storage facilities)*
Social Capital	*The social resources from which individuals can draw for their livelihoods*
Human Capital	*The skills, knowledge, ability to labor, and health of individuals*
Financial Capital	*The financial resources utilized to achieve livelihoods* *Focuses on the availability of financial resources (cash, bank deposits, liquid assets, loans from credit providing institutions), and the flow of financial resources (income, remittances, expenses)*

Table 1 – Types of Capital (Department of International Development, 1999)

When reviewing the impact of an initiative such as SRI on livelihoods, it is essential to not only review the direct impact on those participating in the activity, but also the indirect impact on non-participants (Ashley & Hussein, 2000). Thus, the unintended, as well as the intended, impacts should be explored.

The Three Pillars of Sustainable Development

The concept of sustainable development was solidified under the definition provided by the United Nations Commission on Environment and Development (UNCED). Otherwise known as 'the Brundtland definition', the UNCED defines sustainable development as "*development that meets the needs of the present, without compromising the ability of future generations to meet their own needs*" (McKenzie, 2004; p. 2). Sustainable development, as a concept, has evolved to be composed of three dimensions; otherwise known as the 'three pillars of sustainability' (Bedrich, Janouskova, & Hak, 2012). If development is to be sustainable, it must account for the social, economic, and environmental dimensions of the respective situation or initiative (Bedrich et al.,2012). Sustainable development has been split into these three pillars, because it is argued that the social and economic spheres, are ultimately dependent on the environmental sphere (McKenzie, 2004). Furthermore, human well-being in the social sphere, cannot be maintained in the absence of neither a healthy environment, nor without a well-functioning economy (Bedrich et al., 2012). Thus, the concept of sustainable development is formulated to place equal value on each of the spheres (McKenzie, 2004). It is argued, however, that rather than having sustainability be conceptualised as the intersection of these three spheres, it should be conceptualized as the integration of social, economic, and environmental interests and initiatives (Gibson, 2006). It is argued that unless sustainable development initiatives account for these three dimensions in an integrative way, they will ultimately struggle to integrate the separate findings and initiatives (Gibson, 2006). This is because the nature of sustainability problems, do not fit solely into one of the dimensions; as they are all interrelated (Gibson, 2006). If each of the dimensions is addressed simply in an isolated manner, then development efforts will prove to be a poor fit for the intertwined nature of sustainability problems (Gibson, 2006). In turn, it is argued that when dealing with sustainable development, initiatives must provide multiple, mutually reinforcing, contributions (Gibson, 2006).

Thus, SRI is presented as a promising solution, as it is argued to mutually benefit the three pillars of sustainable development. Thereby, it is argued that it fosters social sustainability, economic sustainability, and environmental sustainability. To better understand how SRI impacts these three spheres, it is important to define and identify what is implied by these three forms of sustainability.

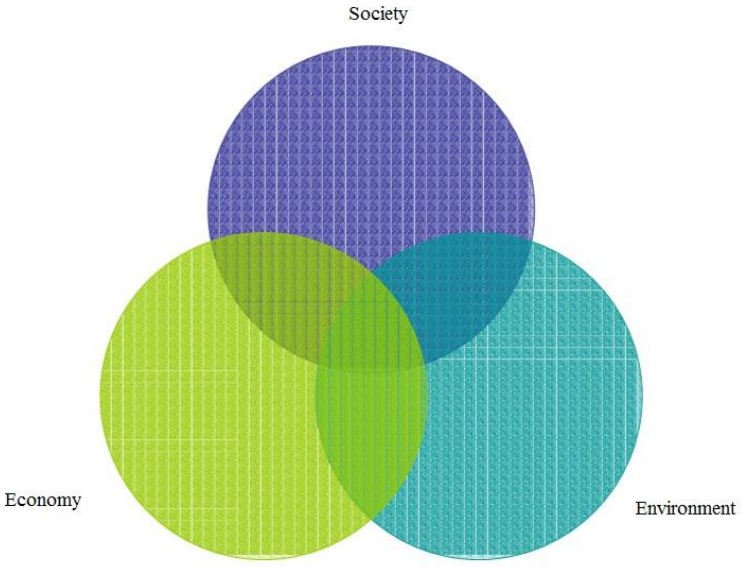


Figure 3 – Three Pillars of Sustainable Development (McKenzie, 2004, p. 5).

Social Sustainability

Social sustainability is a concept that has struggled to receive a concise and uniform definition. In its essence, it can be understood as implying a condition within communities that is life-enhancing; and that processes exist that can achieve this condition (McKenzie, 2004). This remains a rather vague and ambiguous definition, and there is little consensus on what the critical elements of social sustainability are (Bedrich et al., 2012). Nonetheless, social sustainability accounts for the maintenance of human needs, such as: health and well-being; nutrition and food security; shelter; and education (Bedrich et al., 2012). Moreover, a coherent theme and condition for social sustainability, is that there is equitable access to the services that sustain these needs (McKenzie, 2004; Rasul & Thapa, 2004). An additional factor that can be considered when reviewing social sustainability, is the degree of resource self-sufficiency (Rasul & Thapa, 2004). For the sake of this review, the afore mentioned variables are considered when reviewing the social implications of SRI. The notion of equity, however, is expanded to include the extent of empowerment. Resource self-sufficiency does factor into this variable, however the focus is particularly set on gender disparities and gendered empowerment.

SRI as a practice, is considered to benefit the social sphere primarily through promoting food security, and human empowerment. To understand how SRI impacts these elements, it is important to explore them first in more detail.

Food Security

Food security is a concept that has received significant debate as per its meaning and means of measurement. The prevailing definition, that has been established at the 1996 World Food Summit, states that food security exists when "*all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*" (Barrett, 2010, p. 825). In turn, food security is commonly conceptualised as being composed of three dimensions: *the availability, access, and utilization of food* (Faber, Schwabe, & Drimie, 2009). A fourth dimension pertains to the *stability of these three dimensions over time*; in the face of economic, social, natural, and policy shocks and stresses (Faber et al., 2009). Consequently, it is important to distinguish between permanent and transitory food insecurity[9] (Pinstrup-Andersen, 2009).

Reviewing the *availability of food* can be done by evaluating the range of food choices available to an individual/ household; whilst considering their income, the prevailing food prices, and the formal/ informal safety-net arrangements through which food can be accessed (Barrett, 2010). Alternatively, *access to food* refers to the demand side of food insecurity. It is important to review the access to food as its availability does not imply that it is accessible by all members of society (Faber et al., 2009). In turn, reviewing the accessibility of food can shed light on potential uneven inter- and intrahousehold food distribution (Barrett, 2010). Furthermore, access to food also incorporates the capacity for households to response to shocks, such as: price fluctuations, unemployment spells, and loss of livelihood-producing assets (Barrett, 2010). Lastly, the *utilization of food* refers to the way households utilize the food to which they have access (Barrett, 2010). Reviewing utilization, in turn, incorporates an assessment of whether: a household consumes nutritiously essential food items that they can afford? Or do they opt for a nutritiously inferior diet? (Barrett, 2010).

Evidently, these dimensions of food security are inexorably connected with agricultural livelihoods. This occurs not only in terms of the accessibility of food and income, but also in terms of the availability of food and local production diversity. A conceptual overview of the dimensions pertaining to food security is illustrated in *Figure 3*.

[9] Transitory food insecurity describes periodic (seasonal) food insecurity, whereas permanent food insecurity describes a long-term lack of access to sufficient food (Pinstrup-Andersen, 2009).

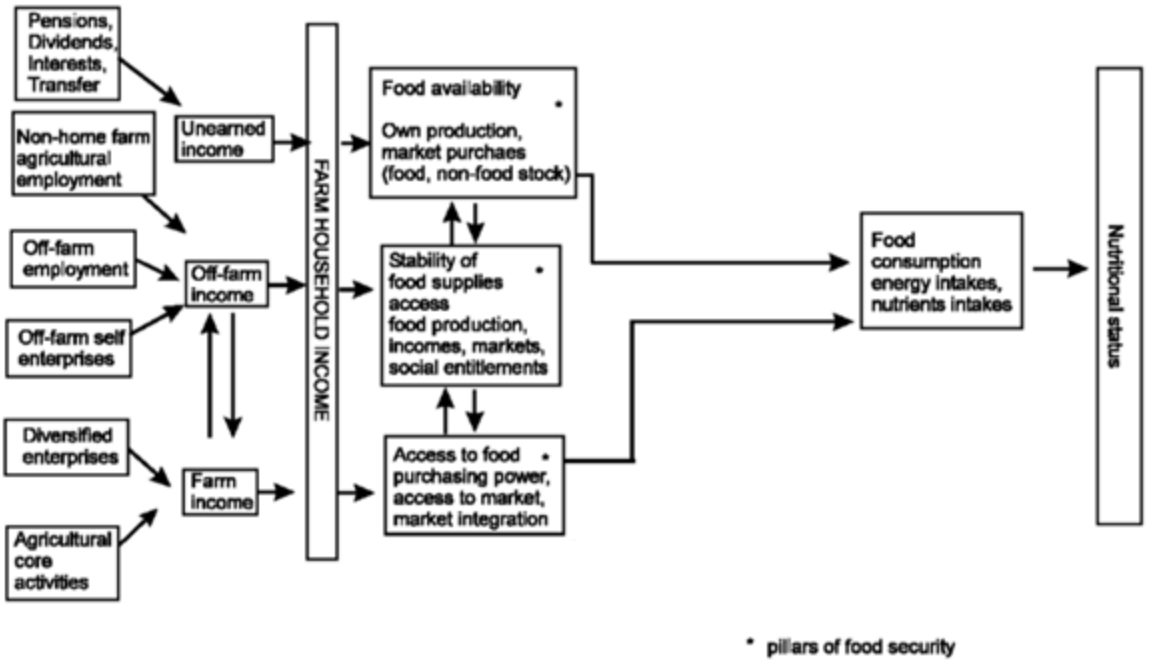


Figure 4 – Food Security Conceptual Model (Babatunde, Omotesho, & Sholotan, 2007).

Measuring levels of food insecurity can be difficult, and in turn typically involves the utilization of proxy indicators (Barrett, 2010). Food security, however, cannot be analyzed as an independent issue; as it is intrinsically connected to the broader socio-economic sphere in which households operate. In turn, it has been argued that food security should be considered a single dimension in the broader concept of livelihood security (Maxwell & Smith, 1992). This enables the review of household food security strategies, to be interpreted in the context of a household's dynamic and complex livelihood strategies (Maxwell & Smith, 1992). Food, although an essential need, does not exist independent of other priority needs that a household may face (Maxwell & Smith, 1992). Utilizing the livelihoods perspective, in turn, provides insight as to how poor households make decisions to spread risk, and how they balance competing interests to subsist in the short- and long-run (Maxwell & Smith, 1992). The livelihoods framework, along with the varying forms of capital, will be discussed further towards the end of the chapter. The varying forms of capital are outlined in *Table 1.*

Agricultural Interventions and Food Security

Evidently there are multiple dimensions that impact food security; and it is for this reason that agricultural productivity does not always correlate with nutritional improvement (Berti, Krasevec, & Fitzgerald, 2003). It is argued that the prospect of nutritional improvement, is dependent on the scope in which agricultural interventions invest in the varying forms of capital[10] of a household (Berti et al., 2003). Interventions that are narrowly focused, may negatively affect other livelihood dimensions[11] (Berti et al., 2003). This argument contests the notion that improvements in financial capital are necessary for the success of agricultural interventions (Berti et al., 2003). This provides a critique against the development potential of producing cash-crops. It is argued, that investments in human and social capital is of importance; and that these can lead to positive nutritional outcomes without improvements in financial capital (Berti et al., 2003). In turn, it is argued that agricultural interventions that invest broadly in the different forms of capital, have higher prospects for achieving nutritional improvement (Berti et al., 2003).

Gender, Agriculture, and Rural Development

A core element of social sustainability, is the principle of equity. As previously mentioned, this review extends the concept of equity to encompass empowerment. Whilst reviewing human empowerment in general is of merit, the focus holds more value if it is set on gender dynamics and disparities. Typically, female-headed rural households own less land, and are poorer than male-headed households (Kennedy & Peters, 1992). In turn, women in rural agricultural areas generally have less access to productive resources and opportunities than men (Food and Agriculture Organization, 2011). This gender gap has been observed for many inputs, assets, and services[12] (Food and Agriculture Organization, 2011). Furthermore, in a study conducted in Uganda, it has been reported that female-owned agricultural plots experienced a lower rate of productivity (Peterman, Quisumbing, Behrman, & Nkonya, 2011). It has been argued, that these gender disparities among the rural poor, ultimately undermine the performance of the agricultural sector in many developing countries (Food and Agriculture Organization, 2011). In turn, closing the rural agricultural gender gap could yield substantial gains for both the rural agricultural sector, and for society as a whole[13] (Food and Agriculture Organization, 2011).

Gender disparities, however, do not only occur between differing gender-headed households, but also amongst members within a household. Thus, when conducting a gender analysis and impact assessment, it is imperative to consider: the division of labor, gender roles, and nature of participation; the access, and control, over resources (capital) and income; and the power, and decision making, dynamics (Resurreccion & Sajor, 2008; Abbott, Mutesi, & Norris, 2015).

[10] Types of capital: *natural capital, physical capital, social capital, human capital, and financial capital* (Berti, Krasevec, & Fitzgerald, 2003).

[11] For example: an intervention that increases the working hours of women, may result in improved food availability and diet; but at the expense of child welfare (Berti et al., 2003).

[12] Land, labor, livestock, education, extension services, financial services, and technology (Food and Agriculture Organization, 2011).

[13] The FAO stated that if women had equal access to productive resources, their yields could improve by 20-30 percent

Economic Sustainability

The concept of economic sustainability, is one that relies heavily on the interconnected nature of the three spheres. The notion of economic sustainability is one that arises out of systems thinking; where the economic system is comprised of four subsystems (Spangenberg, 2005). These subsystems pertain to the: population, society, natural environment, and other economies (Spangenberg, 2005). If an economy is to sustain itself, it is understood that these subsystems must remain healthy, and have positive relations. Within this paradigm, economic sustainability is defined as requiring that economic activity does not undermine the sustainability of the systems it is interacting with (Spangenberg, 2005). This, in turn, implies that economic activity should not threaten the sustainability of: natural systems, social/institutional systems, and human systems (Spangenberg, 2005). The objective, however, remains conventional in the sense that economic activity aims towards achieving economic growth. In turn, the stability and maintenance of cashflow is of due importance. Consequently, when assessing the economic sustainability of rural agricultural households, it is still important to review growth; by the rate of land productivity, yield stability, and profitability (Rasul & Thapa, 2004). These variables, however, only apply to land owning households; thus, employment variables are also considered, to account for labor based households.

Environmental Sustainability

Environmental sustainability can be conceptualised differently depending on whether it be approached from an ecological, or economic, paradigm. From an economic perspective, environmental sustainability is understood to pertain to the maintenance of natural resources; where the sink side [pollution and waste], do not exceed the source side [renewable and non-renewable resources] (Bedrich et al.,2012). The ecological paradigm, however, understands environmental sustainability to entail the maintenance, or improvement, of the integrity of the life supporting systems of Earth (Bedrich et al.,2012). In the beginning of the century, however, the OECD Environmental Strategy defined four criteria for environmental sustainability; being *regeneration, substitutability, assimilation,* and *avoiding irreversibility* (Bedrich et al.,2012). The definition states that the use of renewable resources should not exceed the natural rate of regeneration, and that the use of non-renewable resources should be limited to levels that can be offset by renewable substitutes (Bedrich et al.,2012). Then the definition asserts that the rate of waste disposal into the environment should not exceed the assimilative capacity (Bedrich et al.,2012). The objective of this definition is to avoid irreversible environmental damage by: maintaining the integrity of ecosystems via the effective management of resources; and decoupling environmental pressures from growth in the economy (Bedrich et al.,2012).

When reviewing environmental sustainability on an agricultural household level, the mentioned variables can be supplemented with the use of four indicators: land-use pattern, cropping pattern, soil fertility management, and pest management (Rasul & Thapa, 2004). These supplementary indicators provide a metric to measure the ecological footprint of an agricultural system. Land-use pattern refers to the nature in which the land that is managed by a household is used. This provides insight to land-use elements that either enhance, or supress, the environmental sustainability impact. Cropping pattern, however, factors in: cropping intensity; level of crop diversification; and extent of mixed cropping (Rasul & Thapa, 2004). This essentially provides insight to the level of (planted) biodiversity, and stress levels on available resources. Soil fertility, and pest, management pertains to the use of biological or chemical means (Rasul & Thapa, 2004). This provides insight to the extent that natural soil fertility, and biotic life, are impacted by production methods.

SRI and the Three Pillars of Sustainability

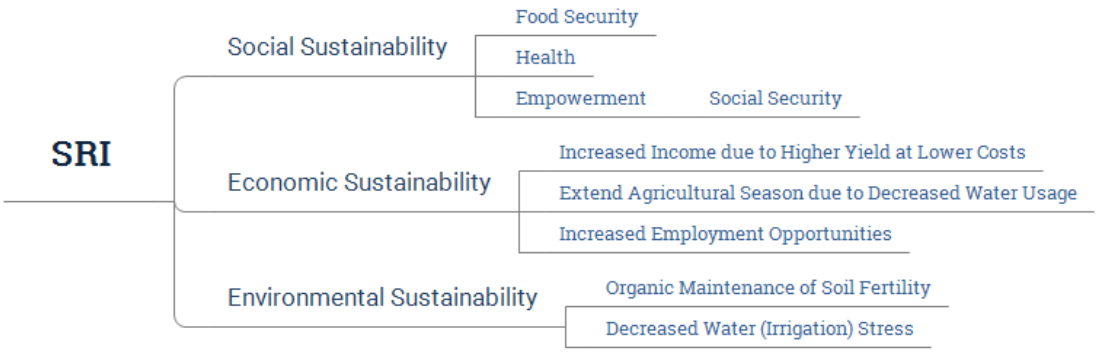


Figure 5 – SRI and the Three Pillars of Sustainability (Gathorne-Hardy et al., 2016; Ly et al., 2012; Uphoff, 2006).

SRI has been considered a promising solution because it is argued to deliver development in the three spheres in an integrative manner. With regards to *social sustainability*, SRI is considered to promote: food security, health, and social empowerment. SRI promotes food security both in terms of availability, and accessibility. The increased availability relates to the higher reported yields that SRI is argued to produce, which in turn increase the supply from which can be eaten. Whilst the increased accessibility, relates to the increased capacity of households to purchase diverse food items; due to the increased income resulting from higher yields. Following the recommended procedure, SRI is considered to encourage better health. This relates to the fact that the practice aims to avoid using synthetic chemicals for soil fertility or pest management. An improvement in health can be argued to result from the reduction in direct contact with harmful chemicals. The last way SRI is said to promote social sustainability is via empowerment and social security. This factor relates to the economic dimension pertaining to the apparent increased income, resulting from higher yields and lower production costs. This capacity to boosts one's income whilst reducing costs, has the potential to benefit households who are suffering from disparity. Furthermore, since the practice recommends the use of organic fertilizer, it relies less on the purchase of external inputs. Due to these two factors, SRI is considered capable of promoting empowerment, resource self-sufficiency, and social security.

As per *economic sustainability*; SRI is considered to foster economic growth, without undermining the sustainability of the other pillars. The economic growth can be considered to arise from the increased income, that results from the higher yields. The higher yields result not only from the spacing and soil fertility considerations, but also from the capacity to extend the agricultural season; due to the decrease in water usage and stress. Furthermore, due to the labor-intensive nature of the process, SRI could result in increased labor demand, which would result in economic development via employment. The economic development resulting from SRI is sustainable, as it does not undermine the human-social (which have been outlined in the previous paragraph), or environmental sphere.

Regarding environmental sustainability, SRI is considered to reduce the degradation of soil by focusing on organic compost, rather than chemical fertilizers. This element, in turn, aims to fulfill the principle of regeneration, substitutability, and assimilation. The use of organic compost: promotes the rate of the regeneration of natural soil fertility; whilst providing a substitute for a chemical input; and reducing the rate of the assimilated chemical discharge. Furthermore, SRI is argued to reduce water stress; which also fulfills the principle of regeneration. Lastly, SRI is considered to contribute to environmental sustainability, as it ultimately aims to decouple environmental pressure from economic growth.

Comprehensive Framework

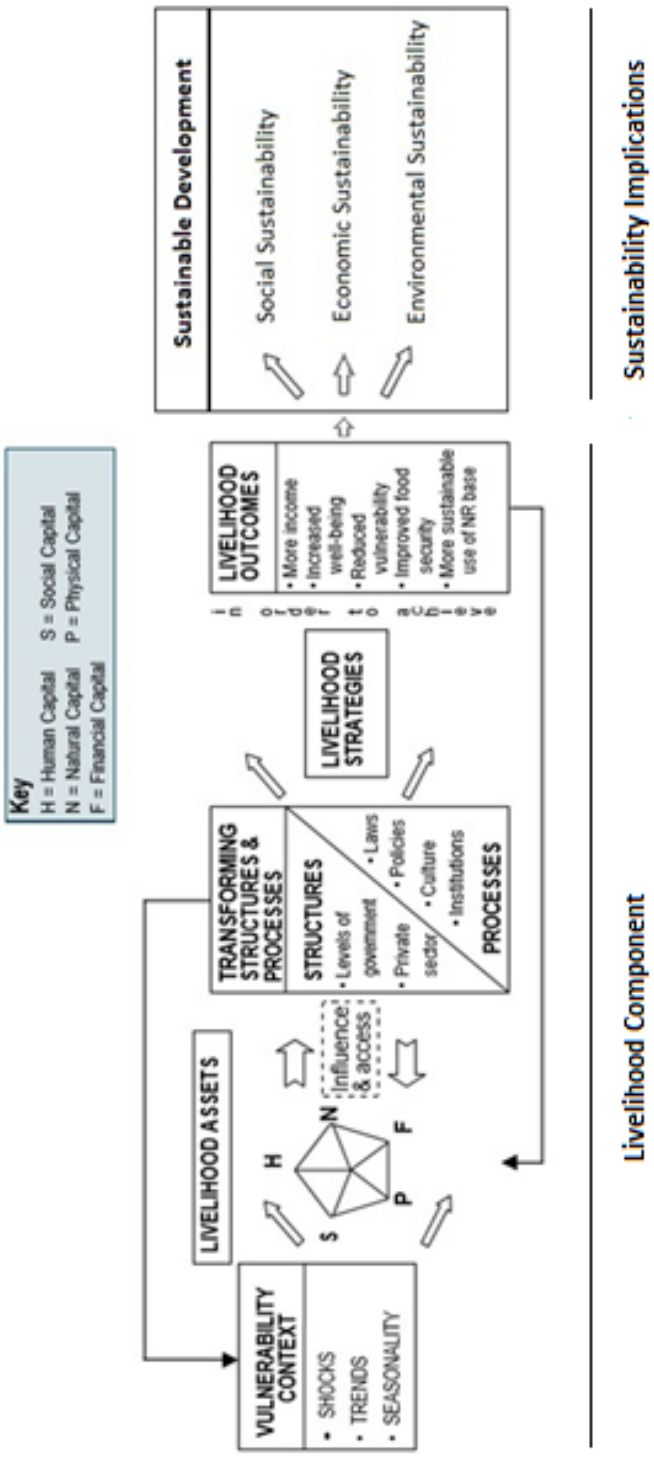


Figure 6 – Comprehensive Impact Framework; Livelihood Component and Sustainability Implications

By reviewing the broader context in which households engage their livelihoods, the sustainable livelihoods framework provides a holistic means to review the nature in which SRI impacts rural development. It considers: how SRI impacts the assets of a household; how this affects their interaction with the vulnerability context and transforming structures; and how this ultimately impacts livelihood outcomes. The people-centered perspective, provides a means to understand the heterogeneous developmental impact that SRI may have. To consider whether SRI is a valid means for sustainable development (i.e. whether it mutually benefits the three spheres), the 'livelihood outcomes' portion of the framework will factor a review of social, economic, and environmental sustainability. This is illustrated in *Figure 6.*

The framework for this research, in turn, is divided into two components. The first component consists of a review of the livelihood implications of SRI. This entails a review of the relationship and impact of SRI on each of the elements of the *Sustainable Livelihoods Framework*. A series of guiding questions is presented in *Table 2,* which will facilitate this part of the analysis. The second component reviews whether the outcomes resulting from SRI fulfill social, economic, and environmental sustainability. These outcomes are reviewed based on the variables outlined prior in this chapter. An overview of the composite variables of the second component is provided in *Figure 7.*

To clarify the results obtained through this research, a scoring index scheme is utilised to analyse the sustainability impact of SRI on rural households. The index is essentially comprised of all the variables that compose the sustainability framework. Each of these variables are then scored on a scale ranging from -2 to +2; where -2 represents 'a negative significant impact of SRI on the variable', and +2 represents 'a significant impact'. The final index score is provided from the sum of these scores, with the utilization of the formula: *Index = ((Actual Value - Minimum Value) / (Maximum Value – Minimum Value)).* In turn, the final index score falls within the range between 0 and 1; where 0 represents 'negative significant impact', 0.5 represents 'no significant impact', and 1 represents 'significant impact'.

This index is utilized as a means of quantifying the degree of the impacts on the varying variables that comprise the sustainability framework utilized for this research. Whilst such a tool does not provide insight to the varying dynamic impacts that arise in a heterogenous fashion, it serves as a useful tool to assess the overall impact; and provide a means of illustrative comparison between commercial and subsistence SRI-based households. This comparative insight, in turn, enables a clarification of the developmental role that SRI plays for subsistence and commercial households. Additionally, it should be acknowledged that the final index score assumes that all variables are weighted evenly; which as will be made evident in the coming chapters, is not necessarily the case. Furthermore, this scheme does not factor in the conditionality of impacts; but these are explored shortly.

Aspect	Questions
Assets and Capital Endowments **[Human Capital, Physical Capital, Financial Capital, Social Capital, Natural Capital]**	*How does the implementation of SRI impact access to assets?* *How does the implementation of SRI change the quality of assets?* *How does the implementation of SRI change the productivity of assets?* *How does the implementation of SRI impact the sustainability of natural resources?* *Does the household have access to social-networks to obtain information regaring SRI?* *In what manner does SRI impact the relations between members of the community?* *Are cash earnings invested in human capital? Or other reserves (financial, physical assets)?* *Are skills acquired that enhance human capital?* *How significant are the impacts of SRI on assets compared to other means of rice production?*
Multiple Livelihood Activities **[On-farm, off-farm, migration, etc.]**	*Does the household engage in multiple livelihood activities?* *How does SRI affect the need and ability to engage in multiple livelihood activities?* *Does SRI foster the development of complementary skills, assets, markets, that can enhance other livelihood activities?* *Does SRI hinder the ability of other households in the community to engage in their livelihood strategies?*
Outcomes (components of improved livelihoods **[Improved well-being, income, empowerment, resource sustainability, reduced vulnerability]**	*Does SRI contribute directly to improved livelihood outcomes? (e.g. food, cash, physical security, empowerment).* *If so, how does it do this?* *How significant are the contributions provided by SRI in comparison to other livelihood activities? (e.g. level & timing of earnings)*
Context **[Natural, economic, and demographic context]**	*Does SRI change household's ability to cope with temporary shocks?* *Does SRI enable household to adapt to permanent change?* *Is the development potential of SRI hindered by contextual barriers?*
Links between components; dynamic change	*Does SRI impact how households invest their income into assets?* *Does SRI change the household's priorities that shape their livelihoods?*

Table 2 – Livelihood Impact Assessment: Guiding Questions (Ashley & Hussein, 2000).

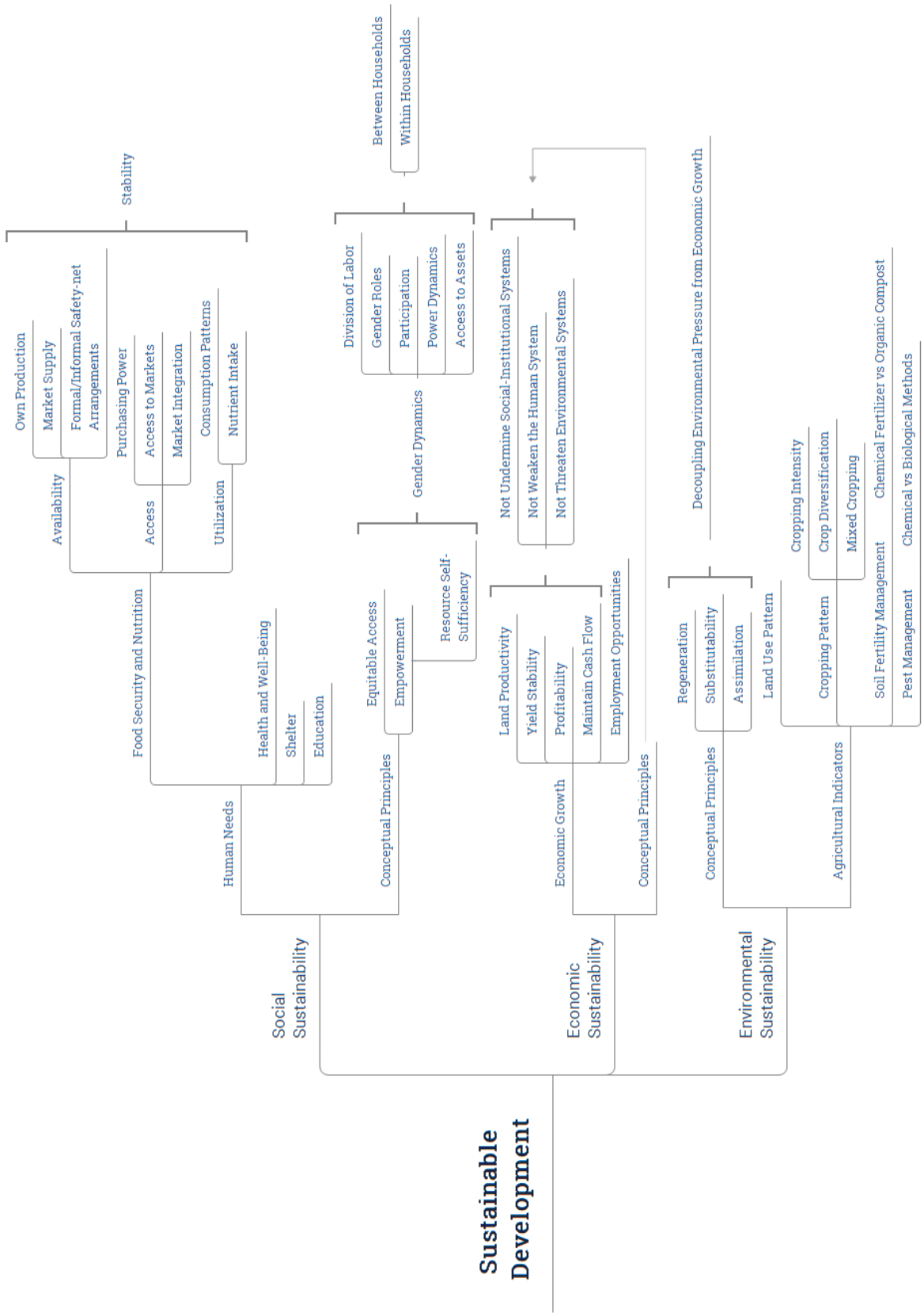


Figure 7 – Variable Overview: Sustainability Implications

Methodology

Overview of Objectives and Research Sub-Questions

To explore the extent that SRI contributes to the sustainable livelihood development of rural Cambodian households, five sub-questions are formulated that reflect the objectives outlined on *Page 2.*

i	*To what extent is SRI effective in boosting yields whilst reducing input costs?*
ii	*What are the social, economic, and environmental implications of SRI; in the context of rural livelihoods?*
iii	*What are the dynamics of these implications? (are they mutually reinforcing, or do they conflict?)*
iv	*To what extent does SRI result in unintended social or economic effects?*
v	*How effective is SRI in fostering sustainable livelihood development in the face of potential contextual barriers?*

Table 3 – Research Sub-Questions

Research Methodology

To explore these guiding questions; the research for this review was administered by conducting interviews with rural rice producing households in Cambodia through April and May of 2017. The interviews were structured on a series of open and direct questions; that were set to explore the two components of the comprehensive framework. The data collected was both qualitative in nature, and quantitative. The data was collected largely by random sampling, although specific respondents were also sought out.

Sample: Respondents

To review the developmental impact of SRI; its effects are contrasted with the livelihood impact of conventional or alternative farming systems. In turn, both SRI implementers, and non-implementers, were interviewed. Among those who did not implement SRI, a division was made between those who have never implemented it – and those who used to practice SRI, but no longer do so. This distinction is made, to better understand the reasons for potential SRI failure; and determine what factors are of most consequence.

In addition, households who managed varying sizes of agricultural land were sought out. The division was made between: households who manage less than 1ha of land; households who manage between 1-3ha of land; and households who manage more than 3ha of land. This distinction is made, to explore the livelihood development impact (and potential) of SRI on households who are burdened by differing requirements, and face varying degrees of disparity. Lastly, to better understand SRI's impact on social security and empowerment, both female and male headed households were targeted. The culmination of these sample divisions provide insight to potential unintended effects between members of a community. An overview of the division of sample groups is illustrated in *Figure 8.* In addition to these general conceptual distinctions for the target responder sample, two model farmers were also identified and interviewed; one of which practices the *Multi-Purpose Farming* strategy, and the other engages in *Organic Agriculture* (ALiSEA, n.d.). A total of 31 respondents were interviewed, and the breakdown of the sample is presented in *Table 4.*

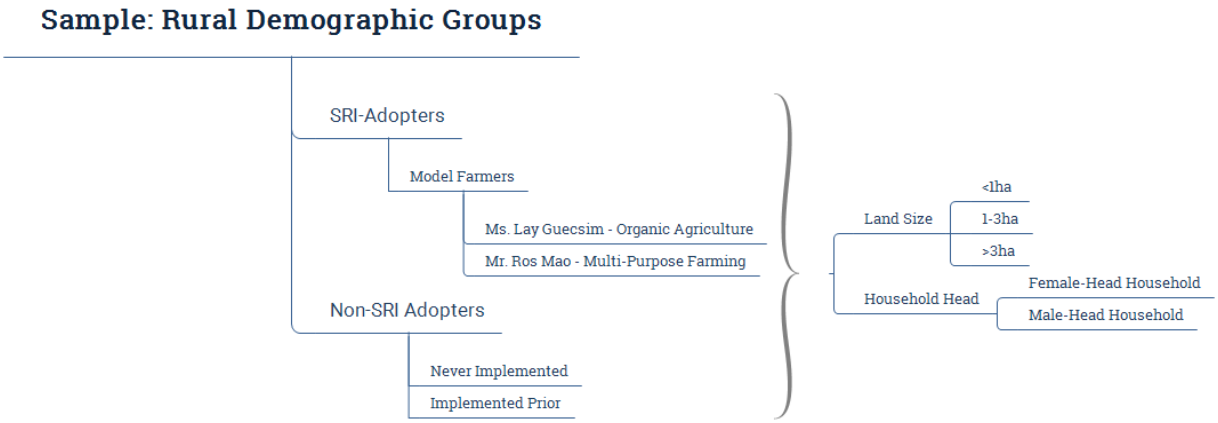


Figure 8 – Sample Demographic Groups

SRI Status	Households	Female Household	Male Household	<1ha	1-3ha	>3ha
SRI Implementer	**11**	3	8	4	7	0
SRI Implemented Prior	**10**	4	6	7	3	0
Never Implemented SRI	**10**	3	7	6	3	1
Total	***31***	*10*	*21*	*17*	*13*	*1*

Table 4 – Sample Size; Respondents

Sample: Location

The research was conducted in the Takeo province. Takeo, located in southern Cambodia, is a major producer of both wet-season and dry-season rice; and in turn is a noteworthy contributor to the Cambodian rice industry (United States Department of Agriculture, 2013). It has been reported that Takeo experiences a surplus in its rice production, relative to its consumption rate (World Food Program, 2005). Despite this, the province faces significant poverty, and significant levels of food insecurity (Asian Development Bank, 2014; Ministry of Health of Cambodia, 2008; World Food Program, 2005).

Takeo, located on the West side of the lower Mekong delta, is comprised of the capital district - Doun Keo, and nine regular districts (Council for the Development of Cambodia, 2013). The sample for this research, encompasses twenty-one communes in five districts; as outlined in *Figure 11*. In recent years, the province has experienced significant drought intensity; affecting the southern region of the province the most severely (World Food Program, 2015). In turn, Takeo has been selected due to the relevancy of its rice industry, and the relevance of the climate impacts that are experienced there. In addition, Takeo presents itself as a suitable sample, due to the size distribution of land ownership. The north-west of the province is marked by households who own less than 1ha of land; whilst inversely, the south-east is marked by households who own enough land for subsistence or commercial purposes (Open Development, n.d.). Lastly, SRI has been promoted by NGOs in Takeo over the past two decades; which has resulted both in the emergence of model farmers, and continuous experimental sites in Tram Kak, Prey Kabbas, and Bati (Asian Center of Innovation for Sustainable Agriculture Intensification, n.d.; Cornell University, n.d.).

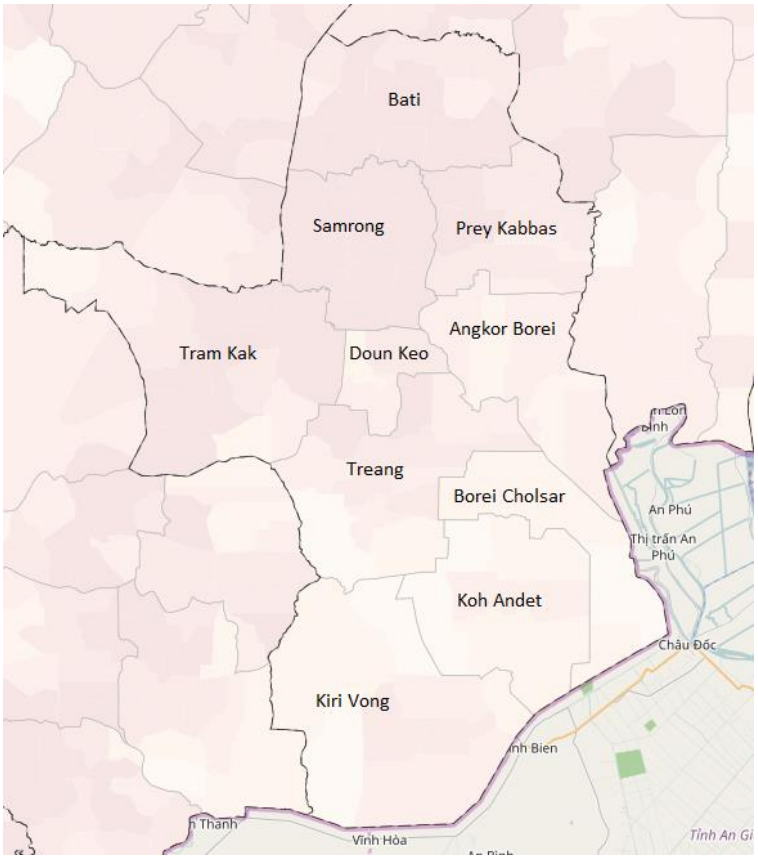


Figure 9 – Takeo Province and Districts (Open Development, n.d.).

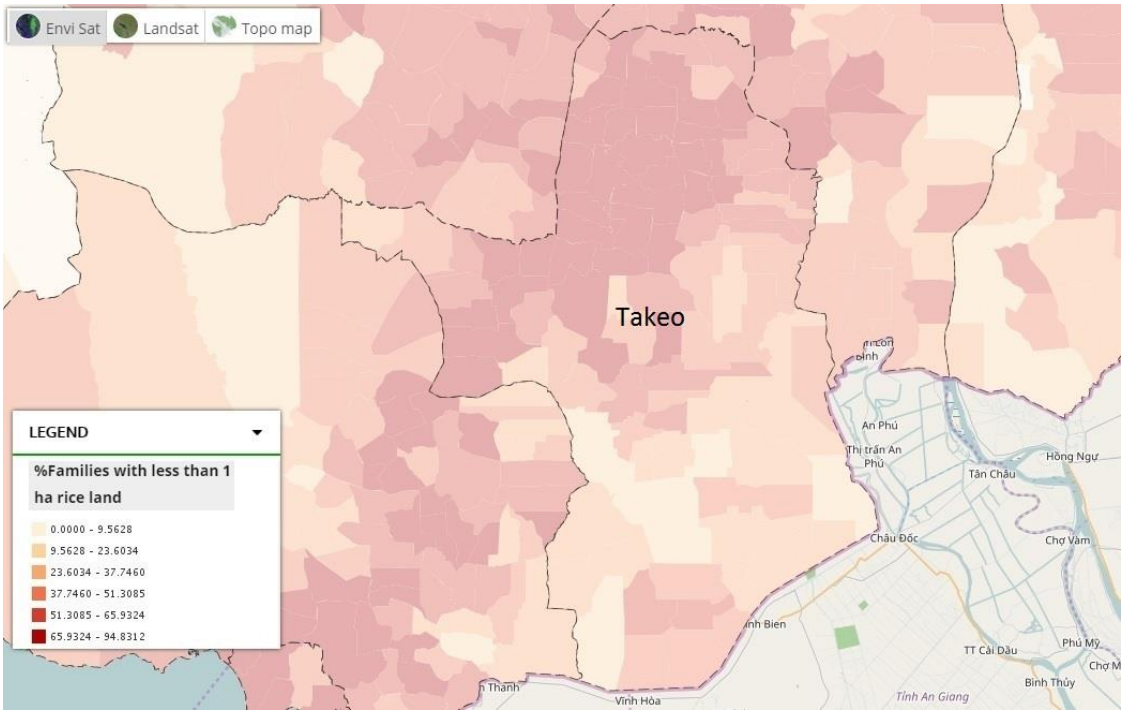
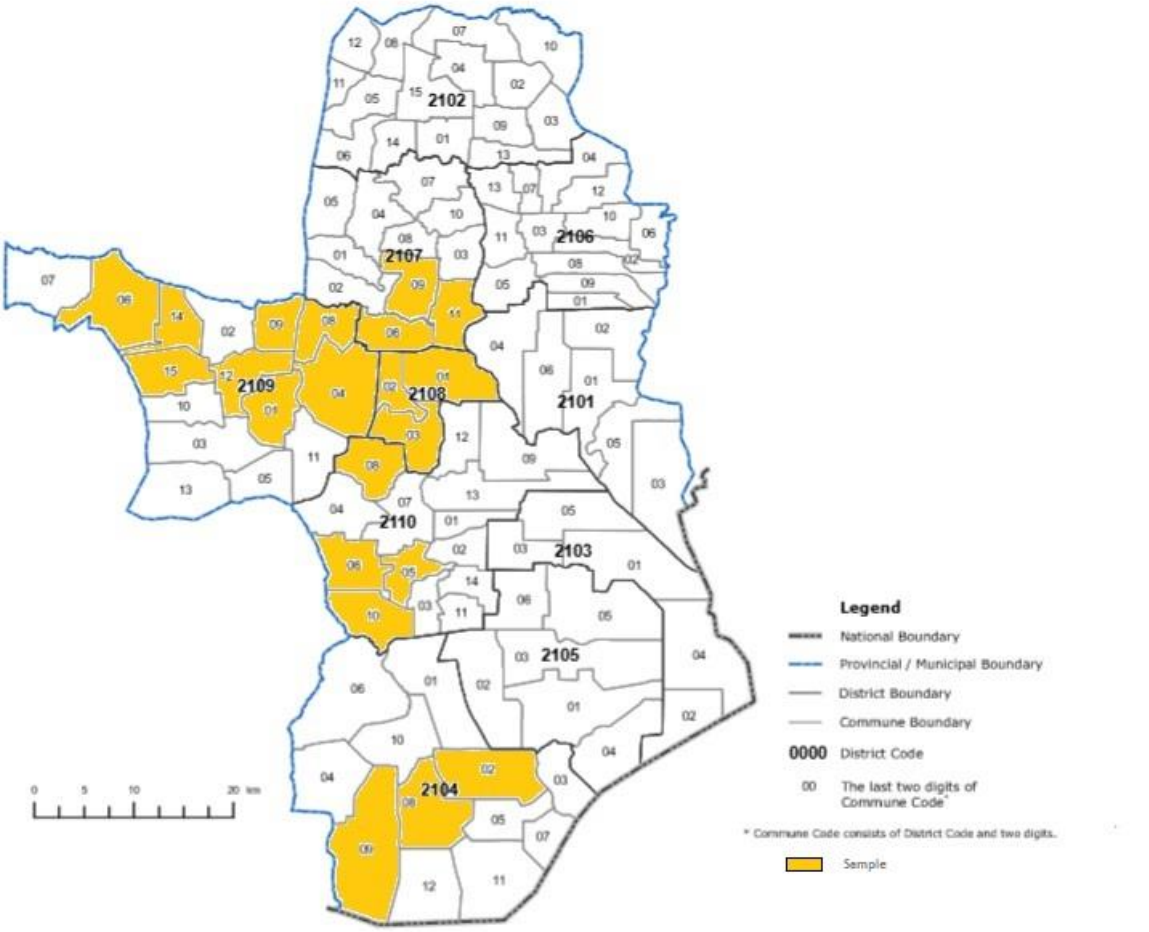


Figure 10 – Takeo, %Families with Less than 1ha Rice Land (Open Development, n.d.).



Code of Province / Municipality, District, and Commune

21 TAKEO

2101 Angkor Borei

210101	Angkor Borei
210102	Ba Srae
210103	Kouk Thlok
210104	Ponley
210105	Preaek Phtoul
210106	Prey Phkoam

2102 Bati

210201	Chambak
210202	Champei
210203	Doung
210204	Kandoeng
210205	Komar Reachea
210206	Krang Leav
210207	Krang Thnong
210208	Lumpong
210209	Pea Ream
210210	Pot Sar
210211	Souphi
210212	Tang Doung
210213	Tnaot
210214	Trapeang Krasang
210215	Trapeang Sab

2103 Bourei Cholsar

210301	Borei Cholsar
210302	Chey Chouk
210303	Doung Khpos
210304	Kampong Krasang
210305	Kouk Pou

2104 Kiri Vong

210401	Angk Prasat
210402	Preah Bat Choan Chum
210403	Kamnab
210404	Kampeaeng
210405	Kiri Chong Kaoh
210406	Kouk Prech
210407	Phnum Den
210408	Prey Ampok
210409	Prey Rumdeng
210410	Ream Andaeuk
210411	Saom
210412	Ta Ou

2105 Kaoh Andaet

210501	Krapum Chhuk
210502	Pech Sar
210503	Prey Khla
210504	Prey Yuthka
210505	Romenh
210506	Thlea Prachum

2106 Prey Kabbas

210601	Angkanh
210602	Ban Kam
210603	Champa
210604	Char
210605	Kampeaeng
210606	Kampong Reab
210607	Kdanh
210608	Pou Rumchak
210609	Prey Kabbas
210610	Prey Lvea
210611	Prey Phdau
210612	Snao
210613	Tang Yab

2107 Samraong

210701	Boeng Tranh Khang Cheung
210702	Boeng Tranh Khang Tboung
210703	Cheung Kuon
210704	Chumreah Pen
210705	Khvav
210706	Lumchang
210707	Rovieng
210708	Samraong
210709	Soengh
210710	Sla
210711	Trea

2108 Doun Kaev

210801	Baray
210802	Roka Khnong
210803	Roka Krau

2109 Tram Kak

210901	Ang Ta Saom
210902	Cheang Tong
210903	Kus
210904	Leay Bour
210905	Nhaeng Nhang
210906	Ou Saray
210907	Trapeang Kranhung
210908	Otdam Souriya
210909	Popel
210910	Samraong
210911	Srae Ronoung
210912	Ta Phem
210913	Tram Kak
210914	Trapeang Thum Khang Cheung
210915	Trapeang Thum Khang Tboung

2110 Treang

211001	Angkanh
211002	Angk Khnaor
211003	Chi Khnar
211004	Khvav
211005	Prambei Mom
211006	Angk Kaev
211007	Prey Sloek
211008	Roneam
211009	Sambuor
211010	Sanlong
211011	Smaong
211012	Srangae
211013	Thlaok
211014	Tralach

* Codes and boundaries are as of February 9, 2009.

Figure 11 – Sample Location (Administrative Areas in Takeo Province by District and Commune, n.d.)

Limitations

Although this research is designed to be quantitative, qualitative, and comprehensive, there are limitations present. First, the fields of gender studies and food security are complex, and contain a multitude of elements that are to be accounted for if these subjects are to be explored in depth. For this research, certain elements from both fields have been incorporated. Although insightful, these selected elements only account for a limited 'part of the picture'.

The second limitation pertains to time. To effectively conduct an impact assessment, it is beneficial to conduct such an analysis over time. This enables for the review of changes over time, and provides a better contextual understanding with regards to relevant changes in the environment and economy. This limitation will partially be accounted for with the use of open questions targeting the respondents perceived changes over time.

Thirdly, for an effective measure of environmental sustainability, it would be of merit to conduct soil quality tests at each of the sample sites. Due to technical limitations, and courtesy to not take a livelihood producing asset (all be it a small portion), this was not done for this research. Rather proxy indicators are utilized that provide an indication of the current condition. These include the 'soil fertility management', and 'pest management', variables.

Lastly, this research is limited by its reliance on spoken testimony. Due to resource and time restrictions, data pertaining to quantitative elements such as crop yields or profit levels, are not measured directly. Rather, all data is obtained via spoken testimony; which could be exaggerated, or understates. This limitation is furthered due to the language barrier between the researcher, and the respondents. The consequent reliance on an interpreter, thus, further skews the limitations associated with the accuracy of spoken testimony.

Results

Results – Overview

The following chapter renders the results obtained through this research. It starts by providing an overview of the general nature of rural livelihoods in Takeo. Following this, the livelihood impact assessment is presented, which is sequenced by the sustainability analysis.

Rural Livelihoods Overview

When it comes to rice production in rural Cambodia, there are some distinctions that can be made to differentiate the varying production strategies. The first distinction pertains to the method of sowing the crop. As mentioned, SRI incorporates either the transplantation of seedlings, or the direct planting of seeds. Conventionally, however, the common practice in Cambodia is to randomly sow the seeds in the field, and let them sprout naturally. The second distinction pertains to the means of irrigation; where either catchment structures are utilized, or households are solely dependent on rainfall patterns. The third distinction, relates to the use of machinery. If machinery is used, it is to fulfil one (or all) of three functions: either to pump water for irrigation; harvest the crop; or spread the seeds. Naturally, the use of machinery requires financial capital. In turn, many of those who are impoverished perform all their agricultural tasks manually.

Rural households in Takeo, can obtain one to two harvests per year; the first of which occurs around August, and the second around December. The ability to obtain a second harvest is largely dependent on whether a household has access to irrigation water during the dry season. Irrigation infrastructure in Takeo is basic, and essentially either utilizes ponds that have been dug on the property, or a ditch that has been constructed by the government (in conjunction with the roads that connect the villages). Due to the high water-table, many ponds are sustained simply from the supply of ground water. Despite this, the irrigation infrastructure in Takeo is still underperforming, as the region suffers from periodic drought. This issue is perpetuated, as many households are unable to install infrastructure (such as a pond) due to the limited size of their land.

Once harvested, the rice is generally sold to a merchant, who then redistributes it further locally or internationally. It is commonly stated that the merchants are typically Vietnamese, and that the raw product is exported to Vietnam for processing. During the harvest periods, the merchants make their way through the villages, and collect the grain directly with the use of large trucks. Whilst this may appear to be a convenient service for the rural communities, it also places them at a disadvantage with regards to price negotiation. Due to the reliance of households on the merchants for transporting their product, the merchants dominate when it comes to setting the price. The price at which rice is sold to merchants among conventional farmers, averaged around 850 KHR per kilogram, although it ranged between 400 KHR per kilogram to 1200 KHR per kilogram. The merchants generally set their focus on the quantity of rice produced, and not the quality. In turn, the general merchant distribution structure is not conducive to SRI, as merchants do not hold higher quality rice in high regard. Furthermore, a consequence of this focus on quantity, meant that merchants would not reach out to households who were only able to sell a small excess after consumption. Such households would sell their grain directly to local mills at a lower price.

Although agriculture is a dominant livelihood strategy in rural Takeo, there are other strategies that are either engaged in along side agricultural work, or solely. The three most dominant alternative livelihood strategies are: owning a small roadside shop; working as labor in a factory; or working as labor in construction. The factory and construction daily wage rate fluctuated between 7 and 10 USD. Factory employment opportunities started to become prominent around 2006, and has since attracted much of

the rural youth. This phenomenon, among other elements, is a factor that has led to the stark decline in the implementation of SRI in Takeo in recent years. Although there are still households and communities who practice SRI, its implementation did not fulfill the momentum that was set out around 2000 by NGOs in the region. A significant number of households are noted to have reverted to conventional rice producing methods. To better understand the reason(s) for this transition, the livelihood impact and sustainability implications are reviewed.

SRI Livelihood Impact

Assets and Capital Endowments

SRI impacts the assets of a household in varying ways, depending on the nature of impact being assessed. In general, SRI appears to have a positive impact on the quality of household assets. It is deduced that the quality of natural soil fertility improves under SRI, due to the use of organic compost. This is a factor that reinforces an improvement in the quality of the rice harvested. Among those who are still implementing SRI, it is consistently reported that SRI results in both bigger grains, and higher quantities, than the conventional methods. The mean yield per hectare for SRI implementers averaged at 4,519 kilograms; which is significantly higher than the mean yield of 2,343 kilograms for conventional producers (refer to *Table 6.*). Both the higher quantity and quality of rice produced, enabled the potential to increase profits; thereby enhancing the quality of the financial capital. The price at which SRI rice is sold averaged at 2,535 KHR per kilogram. The higher quality of rice, enabled some SRI implementers to sell their crop for as high as 4,000 riels per kilogram; which is significantly higher than the mean price of 850 riels per kilogram for conventional producers. This high price, however, is made possible because these households would process and package their own grain, thereby cutting out the merchants who act as middle men. This, in turn, also requires that a household establish their own distribution network and customer base. Not all SRI implementers undertook these ventures. Nonetheless, the mean price at which SRI rice was sold is still significantly higher than the prices conventional producers where obtaining. This potential increase in profits is further reinforced by the decrease in operational costs resulting from SRI. This reduction on operational costs results not only from the shift away from purchasing fertilizer to producing compost, but also from the recommendation to transplant young seedlings; which is done manually as it requires delicate handling, and consequently cuts the expenses typically associated with machinery operating costs.

This factor, however, can also result in a decrease in the quality of human capital in a certain respect. This decrease in human capital pertains to time use patterns and the quality of leisure time. Essentially, the benefits from SRI come at the expense of foregone time due to the manual labor requirements. There are, however, varying opinions on this matter among those who have implemented SRI. The increased time-use burden of SRI is a determining factor, among others, that influenced the transition away from SRI. Contrary, however, those who still implement SRI argued that the increased time-use burden only occurs a few times a year; and if managed effectively, it ultimately frees up time throughout the year to engage in either leisure or other livelihood activities.

It is noted that SRI does appear to result in higher yield rates. Not only are the average productivity rates higher among SRI implementers, but the lowest recorder yield rate was 2,500 kilograms per hectare; which is close to the average rates of conventional producers. Although SRI appears to positively benefit the productivity of land, it does also in some cases demonstrate a reduction in the productivity of time. Abiding by the recommended procedure, SRI requires manual labor execution. Thus, the efficiency of this depends on a household's access to labor (either internally within the household, or externally from the community). It was reported in some cases among those who no longer practice SRI, that they transitioned to the use of machinery to stay competitive during harvest. Essentially, they stated that due to their

limited capacity to obtain enough labor (either due to a lack of supply, or finances), they require the use of machinery to harvest within the same time-window as other members in the community. The importance of operating within this time window, results from the fact that this is when merchants offer the higher price for grain. If a harvest is delayed, in turn, then the household will be required to sell their crop at a lower price. This issue, however, is perpetuated through a reliance on the merchant distribution structure.

The issue of accessing labor is one element that negatively impacts the potential to capitalize on, and perform, SRI. This issue is exasperated by the trend in which the rural youth are transitioning towards the construction and factory industries for employment opportunities. Not only do these industries limit the supply of available labor, but they have also led to an increase in the average daily labor wage rate. Prior to the emergence of these alternative industries, the wage rate for agricultural labor was around 2 USD per day. Since then, however, laborers have been able to demand wage rates of 7 to 10 USD per day, as this is on par with the construction and factory rates. In turn, the rural demographic is becoming dominated by an elderly population, who increasingly struggle to perform manual labor tasks as they age. This is, ultimately, one of the main reasons that has driven households to revert to conventional means of production after attempting SRI.

Although SRI is limited by access to labor, the practice does in some cases indirectly enable access to other resources; when there exists a coop or collective. In most of the cases where SRI is still implemented among the sample respondents, there is a unified collective that acts as a supporting foundation. Although SRI in-and-of-itself may not directly impact access to assets, such collectives that are closely tied to SRI implementers do facilitate access to not only assets, but also markets. Through collectives, members can obtain higher quality seed and organic compost, access information, and gain access to markets in which the crop can be sold at a higher price. Labor sharing was a phenomenon among these collectives in the past; however, this activity has declined as many members transitioned to the use of machinery (due to their economic development and ability to afford the overhead costs), and thus no longer offered, or required, labor assistance. These collectives typically do not arise independently, but result from NGO involvement that promoted the use of SRI. These NGOs play an essential role in spreading awareness about SRI, and are critical in establishing well-functioning SRI producer-distributor networks. The importance in this initial push by NGOs is made evident by the fact that the two districts from the sample (Tram Kak and Treang) in which SRI was still practiced, are also the only two districts that are noted to have experienced NGO presence (pertaining to SRI promotion). Furthermore, a leading reason for the lack of will to implement SRI, is due to a lack of NGO presence. It is repeatedly noted among those who have never adopted SRI, that they are skeptical about the practice because they have never seen it in action. In turn, having NGOs be present in a community, and initiate pilot projects, severely increases the potential for adoption. Such NGOs are not only critical for raising awareness and providing information, but they are also essential in laying the foundational social networks, that are to be used and expanded from by SRI implementers in the future. This point is made evident when comparing the impact of two different NGOs, *CEDAC and Regina*, in the respective districts of their involvement. Among the respondents, the highest concentration of currently active SRI implementers is in Tram Kak; where CEDAC operates. Contrary, the highest concentration of those who reverted away from SRI implementation was noted to be in Treang; where Regina had once operated. A major difference between the two NGOs, is that Regina simply focused on teaching households the method of SRI; whereas CEDAC continues to focus on both the practice, and connecting households with initial markets. In turn, the lack of focus of Regina to establish lasting networks, is a factor that played an important role in the failure of SRI's continued adoption in the area.

Within the province of Takeo, in turn, access to social networks to obtain information is limited to certain districts. Where NGO involvement was successful in fostering the establishment of social

networks, the emergence of collectives is also prominent; as they are designed to further the independent expansion of households into new markets. Such collectives are noted to strengthen the relations between its members; although tensions do rise between collective members, and the rest of the proximate community. In Tram Kak, where collectives have been successful in fostering socio-economic development among its members, tensions arise from non-collective members who become jealous. Although no restrictions were identified for joining the collectives, many non-members are reluctant to join due to a lack of trust. This can in large be associated with the polarity of political affiliation throughout Cambodia. This element if complicated further by the fact that one of CEDAC's leading members has recently formed his own political party. In turn, non-members at times perceive such collectives to be politically driven; although this was repeatedly denied by collective members.

Thus, when compared with conventional methods, SRI can have a significant impact on livelihood assets. This arises primarily through the financial, social, and human benefits just outlined. It is important to note, however, that these benefits only arise in an enabling environment where producers are effectively able to meet the labor requirements, and able to access markets and supportive information.

Multiple Livelihood Activities

As outlined, under the right circumstances, SRI has the capacity to significantly improve income. The impact this has on the need to engage in multiple livelihood strategies varies depending on the needs and status of the household. The common trend observed was that SRI reduced the need to engage in multiple livelihood strategies. The increased income, however, was most commonly reinvested back into production; either to expand current production, or to cultivate additional crops. The second priority that followed is financing the education of the children in the household. This, however, is mostly apparent for households who owned land large enough for expansion (roughly at least 0.8 to 1 hectare). The priority for reinvestment changes for SRI households whose properties are only sufficient for subsistence purposes (i.e. around 0.5 hectare). Among those households, the priority of reinvestment was focused more on educating the children. Considering that there is no pension system in Cambodia, it is deduced that this investment by subsistence households into their children is a form of social security. Rather, the educated children will have an enhanced opportunity to secure a better paying job, and in turn support the parents as they become elderly.

The impact that SRI, in turn, has on the need and ability to engage in multiple livelihoods is dependent on the size of land that is managed. If the land is big enough that it can be profited from (rather than serve subsistence purposes), then the financial return from SRI reduces the need to engage in multiple livelihood strategies. In the case of subsistence agricultural households, the need to engage in multiple livelihood strategies is still present. The higher yield rates obtained via SRI, enable such households to sell some excess (even if it is just a small quantity) for extra income[14]. Although the excess income derived from such sales is already a vast improvement from what can be achieved through conventional methods, it is not sufficient to foster growth beyond surviving year to year on the limited quantity that can be grown. In turn, if such households are inclined to develop economically, they are still required to engage in alternative livelihood strategies (although this need is slightly diminished via the income from selling excess crop). It is claimed, however, that the manual labor requirements of SRI, diminishes the time availability for such households to engage in alternative livelihood strategies. Thus, for subsistence farming households, SRI poses a tradeoff between securing an adequate supply of food and enabling economic development.

[14] It should be noted that this is only made possible in the cases that there is a well-functioning collective that holds a reliable customer base.

Despite being a method of production that requires more skill and procedure than its conventional counterparts, SRI does little to provide complementary skills that can enhance other livelihood strategies. The only application in which the skills can enhance other livelihood activities is if one were to work as labor on another SRI farm. The capacity to find SRI related work, however, is hindered by the reduction in the number of SRI implementers. This may appear to contradict an earlier statement regarding the diminished ability implement SRI due to the poor supply of labor, but both are a part of a reinforcing loop. As illustrated in *Figure 12.*, the entry of new industrial (factory and construction) employment opportunities, results in an increase in the supply of industrial labor; as members of the rural community are attracted by higher wages and indoor working conditions. This, then leads to a reduction in the supply of agricultural labor, which then leads to a reduction in the rate of SRI implementation. The reduction in SRI implementation, consequently, leads to a reduction in SRI specific labor demand, which then leads to an increase in the supply of industrial labor. This increase in the supply of industrial labor, encourages more factories and construction projects to enter the market; thereby perpetuating the loop.

Lastly, although via this loop the diminishment of SRI implementation, may result in the diminished capacity for those with the skillset to secure SRI related employment - the presence of SRI does not diminish the capacity of others in the community to engage in their livelihood strategy. Both SRI and conventional producers utilize separate distribution networks, and both typically rely on a different set of resources; as one is primarily chemically based, whilst the other is typically organic based. Furthermore, there are no apparent barriers for conventional households to obtain information about SRI, or to join a SRI collective (if a collective, or relevant NGO, is present in a community.

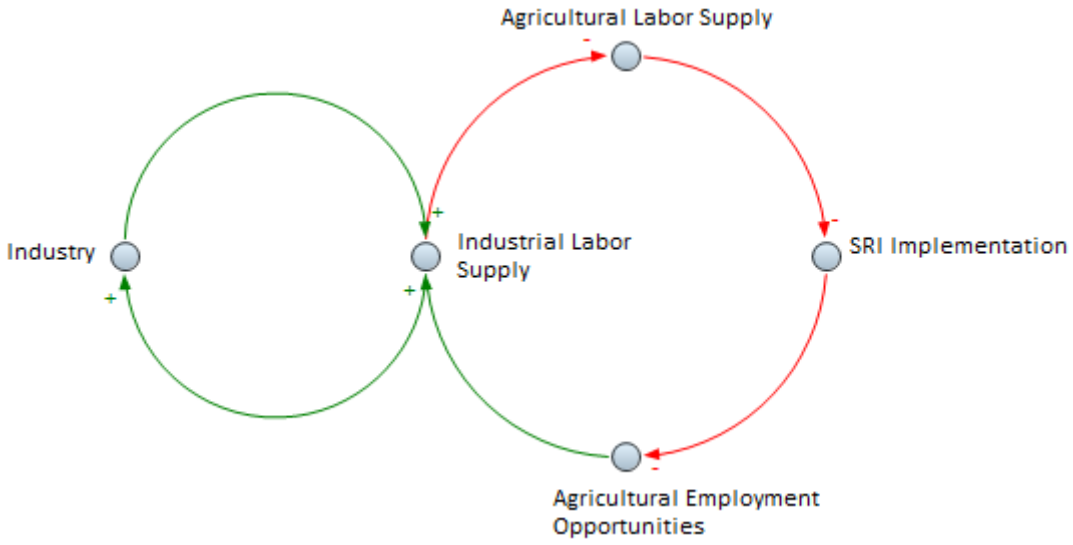


Figure 12 – Causal Relationship Between Agricultural Labor Supply, and Industrial Labor Supply

Outcomes and Context

It is apparent that SRI has the potential to result in positive livelihood outcomes. The positive livelihood outcomes of financial growth, and securing a supply for consumption, can directly be associated with the higher yields and quality of grain resulting from SRI. The nature and extent of these benefits however, is determined by the size of land that is managed, and the extent to which contextual barriers are present and overcome. The size of land ultimately determines the extent to which a household can capitalize financially from SRI implementation. In addition, the size of land also determines the extent to which SRI can be implemented practically. It is identified that two important elements for SRI's success is the use of

organic compost and effective water management. Both elements require enough land; either to house and manage the livestock whose manure is used to produce compost, or to have a form of water infrastructure such as a pond. It is for this reason that among the respondents, most of the SRI implementers managed land that exceeds 1 ha, whereas most of those who do not practice SRI manage land that is less than 1ha; this is illustrated in *Table 4.* Thus, although SRI has the potential to provide livelihood benefits for subsistence farmers under the right circumstances, the livelihood improvement potential is significantly higher for households who manage land that exceeds 1 ha.

Although more land does enable the overcoming of the irrigation and natural fertility issues, it does face the barrier of limited labor. Naturally, the more land that is managed, then the more manual labor will be required to implement the system. Among the successful SRI implementers, it is noted that a household of three people can manage the labor requirements of around 1 ha. The determining factor, then, is the physical capacity of the household members and their drive for growth. In turn, the average age and health of a household determines the potential for successful SRI implementation.

Despite having the potential to improve livelihoods, SRI does suffer from an increased vulnerability to climate variability. This vulnerability pertains primarily to drought. During the initial transplantation phase, it is essential that the young crop receive around three weeks of rainfall (as the first crop is planted right after the dry season, and ponds may be inadequate to provide irrigation water). If rainfall patterns are inadequate during this crucial period, then the transplants die and the household is left without a crop for the season. This phenomenon is one of the reasons that has lead households to revert to, or continue, practicing conventional methods of rice production. The conventional practice involves simply spreading the seeds (after some preparation) in an open field; where they are left to germinate naturally according to rainfall patterns. This method, in turn, is far less sensitive to periodic dry periods early in the season. In addition, the higher number of seeds used under conventional methods furthers the chance of successful germination.

Thus, although SRI reduces the stress on water supplies, it does little to provide resilience to periodic drought. The benefits of reduced water stress manifest primarily in its ability to extend an agricultural season, or increase the number of harvests in a year. In addition to providing poor resilience to drought, SRI is ineffective in conditions where periodic flooding occurs. An essential element for SRI success is that soil conditions be kept aerobic. SRI, in turn, would be less applicable and effective in regions of the Mekong Basin that experience more regular flooding.

Sustainability Implications

SRI has the potential to directly have a positive impact on the financial capital of a household, and the supply of their sustenance. To evaluate whether these livelihood outcomes fulfill the criteria of achieving sustainable development, the social, economic, and environmental sustainability implications are evaluated.

Social Sustainability – Human Needs

The social impact of SRI is deduced to provide a mixed set of results; although it has the potential to benefit human needs. It is consistently reported among current SRI implementers that they perceive the organic means through which SRI is produced to provide health benefits; as they no longer handle chemicals, or consume food on which chemicals have been applied. In addition to these benefits, households who can capitalize financially from their SRI production are noted to be more financially able to purchase medication when needed. In some cases where households lacked the physical capacity to implement SRI on the totality of their available land, SRI would be implemented on a small portion of land that is dedicated to producing for self-consumption. It should be noted that although SRI has the potential to provide attractive economic returns, some households would rather choose to dedicate the limited SRI production for consumption rather than economic gain. These households collectively claimed that they are concerned about the quality of their food, and do not trust the non-organic alternatives in local markets. In this manner, SRI is considered to provide a direct positive impact on households; even under the condition where labor requirements may not be able to be met for a full-scale SRI system. The extent to which these health benefits are made aware of, however, is dependent on the availability of information via NGO involvement. Every case where a respondent is aware of the health concerns regarding synthetic agrochemicals, an NGO had spread the information in the community. In turn, when households who had never engaged with such an NGO were asked about their perception of SRI, their paradigm is primarily set on the yield and economic return potential, rather than health concerns.

With regards to the capacity to provide shelter, SRI has little impact on this human need aspect. In every case, regardless of whether SRI is implemented or not, rural agricultural households have shelter of a similar status. Despite the increased economic returns among SRI implementers, concerns regarding shelter are not prominent when prioritizing financial reinvestment. The opposite dynamic applies to the relationship between SRI and the general education of household members. Among SRI implementers who are able to capitalize from it, investment into education consistently came second to reinvesting into production. Although the prioritization of education does fall second, it still remains a priority. Households who are unable to capitalize from their SRI production, consequently, only prioritize the education of their children when they can do so with the financial capital available from additional livelihood strategies. In cases where no additional livelihood strategies are undertaken, such households do not prioritize education, but rather invest what little they can to diversify their production for consumption.

The impact of SRI on the general education of the children of a household is further made apparent, when comparisons are made to the education levels among non-SRI implementers. A common occurrence among these households is that the children are subject to work as factory labor. Their education, in turn, is foregone for the income they can generate for the household. This occurrence is typically coupled with households who produce with the use of machinery. The additional income provided by the child factory labor, in turn, is often utilized to assist in financing the use of machinery, or to pay off production related debts. Sending children to work in factories becomes a livelihood option not only because it generates additional income, but also because it cuts the education related expenses that would otherwise be incurred. The collective cost (for food, school supplies, rent etc.) for sending children to school averages around 2.5 USD per day. Assuming five-day school weeks, the average monthly cost

of sending a child to school is around 50 USD. Considering that a typical household will have three to eight children, education expenses can quickly become unaffordable. If a household wishes to send their children to a private school, where they can learn English and later obtain better opportunities, there is an additional fee of 15 USD per month per child. Thus, by reducing production related expenses, SRI reduces the need for households to rely on additional income from child employment, and enables households to allocate more of their financial capital towards financing education.

It is apparent that SRI does have a positive impact on increasing the rate of education among rural children. This impact, however, is only direct in situations where households manage land that exceeds 1 ha; which in turn can be capitalized from. The impact is indirect in cases where households implement SRI for sustenance, but employ additional livelihood strategies. In this case, the reduced operational costs of SRI, reduces the need to direct income from additional livelihood strategies into production. Thus, it is evident that SRI is capable of relieving households from the trade-off that they otherwise would face; between investing in children and investing in agricultural production.

An additional indirect impact of SRI on education, is the broader information and education that is provided by NGOs who promote the practice. Whilst the link in this case between education and SRI as a practice is indirect, it is still noteworthy as it impacts human and social capital in a positive manner. As outlined, the knowledge among SRI implementers regarding the health risks of synthetic agrochemicals was obtained in unison with the SRI training provided by the respective NGO. Furthermore, in cases where NGO involvement led to currently successful SRI implementers, the support from NGOs led to the establishment of collectives, which act as knowledge transfer centers. In Takeo, one case is identified where a collective set up a training center in one of its member's homes. [15]

Social Sustainability – Food Security

Whilst having little impact on obtaining or developing shelter, SRI is noted to potentially have a positive impact on the health and well-being of a household; and on enabling education among rural children. The impact of SRI on food security, however, may only provide superficial benefits. Nevertheless, SRI does positively impact food security for two categories of applicable households. The first of which are SRI implementers who manage land mainly for subsistence purposes. Among this category of households, SRI strengthens food security primarily by increasing the availability of food. Rice is a staple component of rural diets in Cambodia, and increasing its supply increases the direct availability of rice to be consumed by subsistence oriented households. Whilst SRI strengthens food security in this one dimension, it does little to directly contribute to a diverse diet. As outlined in the definition for food security provided prior, an integral component is that nutritional requirements be met. In turn, for subsistence based households, SRI does little to directly impact the utilization of food; as it does not provide a holistic intake of nutrients, and does little to change consumption patterns. Although, under these circumstances SRI provides limited benefit to the availability of a diverse nutritious diet, the benefits it provides in increasing the availability of rice alone is still of merit. It should be noted, however, that among this category of households, the potential benefit of SRI applies particularly to households whose members are too old to work in construction and factories, but who are still physically capable of performing SRI related tasks.

The second category of households, concerns those who operate on a scale from which can be capitalized financially. Among such households, SRI provides benefits to food security primarily through its availability and consequent utilization. In objective terms, SRI also benefits the accessibility of food as a household's purchasing power increases with the increased income. As has been made evident, however, purchasing food does not appear to be a priority for financial reinvestment. In turn, this

[15] The member would provide SRI courses that are divided into eight components; four of which are theoretical, and four of which are practical.

improvement in purchasing power for food is not enacted upon in the face of other priorities. The priorities for investment fall namely on the agricultural system, or education. The first of these two, consequently, has an indirect impact on the availability and utilization of food. As financial capital is reinvested into production systems, households will typically engage in, and expand, the production of other crops. In turn; SRI not only directly impacts the supply of rice from which can be consumed, but also indirectly impacts the supply of diverse alternatives that contribute to a more nutritiously balanced diet and result from financial reinvestment.

It should be noted, that the impact of SRI on the availability of diverse food items is more significant with respect to availability over time, rather than the spectrum of diversity. Aside from those who can only produce enough for subsistence purposes, the diet among SRI and non-SRI implementers is consistent in terms of food groups. Both sides typically consume rice, protein, and some vegetables. Protein typically consists of fish that grow in ponds; or chicken, beef, or pork that are raised locally. Vegetables, in turn, generally consist of a selection from: green beans, pumpkins, cucumber, melon, lettuce, tomato, eggplant, chili, and garlic. In addition to rice, many non-SRI implementers will typically also grow some additional vegetables. The notable difference, however, is that non-SRI implementers will typically only grow a small quantity (and limited selection) of alternative food items; and in turn only have enough to fulfill transitory periods of food security throughout a year. The additional income from SRI, in turn, enables households to substantially expand their current vegetable production to enable a consistent supply through a year. This expansion of production, furthermore, is not only enabled by the increased financial capital that results from SRI, but also by the increased water availability; that results from the decreased water stress associated with SRI. This increased availability of water, in turn, enables households to grow vegetables not only alongside the rice crops, but also in-between the two rice cropping cycles; which secures supply throughout the year.

It is evident that the main way SRI impacts food security, is via the availability dimension. In an enabling context, SRI has the potential to both directly and indirectly impact the availability of food for those implementing the system. The most prominent impact is the direct effect of the increased yields of rice on consumption. Although this impact is significant, the more notable impact is the indirect effect of SRI enabled financial reinvestment on the availability of diverse food items. This impact is of more significance due to the consequential nutritional effect. In turn, such financial reinvestments affect not only the availability of food, but also its utilization. Although in categorical terms, the staple diet between SRI and non-SRI implementers (who can capitalize from their production) both typically include vegetables, it should be noted that the financial reinvestment enabled by SRI can lead to more diversity among the vegetables that are consumed. Under such circumstances, SRI positively impacts a household's consumption pattern by enabling a more substantial and holistic diet. The utilization of food for subsistence based households, however, is impacted little by SRI implementation. Such households are typically less able to grow anything aside from rice due to the limited size of their land, and other operational capital. In turn, the resulting increased yields provided by SRI under such circumstances, have little effect on the nutritional intake and consumption patterns of subsistence households.

It is worthy to note, that SRI impacts the availability of diverse food items not only indirectly for commercial households implementing SRI, but also for non-SRI adopting households in proximity. Since SRI adopters who invest into diversifying their production do so for commercial purposes, these ventures also result in an increased availability of diverse food items in local markets. Naturally, although SRI can have an indirect impact on the availability of food items in local markets, it does little to affect the accessibility by the remaining non-SRI households in the community. The consumers of local markets, are typically households who rely on construction or factory work for income. In turn, their accessibility is primarily determined by other factors such as their wage rate. Abiding by the classical economic theory of supply and demand, one may theorize that the resulting increased supply of diverse food items

(resulting indirectly from SRI) may drive local food prices down; thereby indirectly increasing the purchasing power of local consumers without necessitating a change in their income. This effect, however, has not been observed in the sample, as prices for food items averaged around the same rates between SRI dominated and SRI-non-dominated communities. Failure to observe this trend, however, could be due to the limited scale at which SRI is adopted in the broader rural community. Consequently, since SRI adoption is not widespread, the indirect impact on food supply and price may be insignificant on the scale that is measured for this research.

Further, in addition to its effect on the availability and utilization of food, SRI has a direct impact on the accessibility of food only in objective terms for households who can capitalize from their SRI production. Subsistence farming households, in turn, experience little impact from SRI on their capacity to access diverse food. Since rice production is centered on subsistence consumption, the SRI for such households does not provide adequate financial returns to warrant an improvement in a household's purchasing power for alternative food items. As noted, the direct impact of SRI on the accessibility of diverse food by commercial households, is insignificant as there are other dominating priorities for financial spending. There is, however, also another indirect effect of SRI on the accessibility of food that is noteworthy. This manifests through the existence of the collectives that are associated with SRI. It is reported in some instances, that collectives will share their produce for consumption if a member suffers from food insecurity due to an underperforming crop. The expectation under such circumstances, is that the member receiving aid in a given year is to aid other members if, and when, needed at a later point in time. This form of informal safety-net, in turn, aids struggling member households not only with accessing the food they need, but also in what is available to them. Such a safety-net system is significant when the consideration is held that the Cambodian government does not offer any food-aid or pension assistance. Although this beneficial safety-net scheme is not a direct consequence of the technicalities behind the SRI procedure, it is an indirect consequence as it manifests in the collectives that are vital to the successful implementation of SRI.

In sum, within an enabling environment, SRI has the potential to positively impact varying aspects of food security; both for its implementers, and for non-implementers in proximity. These benefits, however, may only be superficial if one considers the stability of these impacts in the contextual environment. In one respect, SRI is capable of extending the season and quantity of diverse food items that are grown by a commercial-based household. In this respect, SRI contributes to the stability of the availability of food items for a holistic diet. This score on stability, however, is undermined when one considers SRI's vulnerability to periodic drought. In objective terms, SRI is considered to provide resilience to drought due to its reduced stress on irrigation water. This effect, however, is only valid under conditions where there is an adequate supply of water. When rural farmers start the cropping cycle after the dry-season, the supply of water in catchment basins (such as ponds) is limited; thereby placing the dependence during this period on natural rainfall patterns. The risk of failure that this dependence places on early SRI transplants that are vulnerable, ultimately undermines the net effect of SRI on food security. The trade-off, in turn, falls between practicing SRI, which has a high return potential, but also a high risk of failure – and practicing conventional methods, that have a lower return potential, but a higher likelihood of stable success. To effectively evaluate this trade-off, it must be done with the consideration of the degree of food insecurity of a household, the extent to which they must engage in coping strategies, and their available assets.

With this consideration, it is evident that the food security impact of SRI affects rural households of differing status in different ways. Namely, for subsistence based households, SRI has the potential to reduce food insecurity; whilst for commercial based households, SRI has the potential to strengthen food security. The higher yields that can result from SRI, ultimately reduces the extent to which subsistence

households must cope with periods of food insecurity that may result from an otherwise inadequate crop. Conversely, SRI strengthens the food security of commercial based households as it indirectly can improve the supply and diversity of nutritious food items. In turn, the value offered by SRI to food insecure households exceeds the risk of failure. Although in these cases, an event of crop failure will have a more detrimental effect, due to the higher degree of vulnerability that these households experience.

Thus, although the impact of SRI on food security benefits subsistence and commercially based households in differing ways, the benefits provided to subsistence households is of more significance; as reducing food insecurity is ultimately a case of ensuring survival. Contrary to this, however, it is subsistence households who struggle more to effectively implement SRI systems; due to the limited capacity to install irrigation infrastructure on small plots of land.

Social Sustainability – Equity and Empowerment

The social sustainability implications of SRI regarding equity, empowerment, and gender dynamics offers a mixed set of results; although overall the impact is deduced to be positive. The impact is undermined particularly with regards to equity; and occurs on a few different levels. A key facet for the introduction of SRI in rural Cambodia is the presence of NGOs. Whilst no discriminative barriers are identified for obtaining information or training from NGOs, the scope of their immediate involvement is limited in Takeo. Due to limited resources, the direct involvement of NGOs, such a CEDAC or Regina, is limited not only to certain districts, but also to certain villages within communes. Thus, households who are fortunate to reside in a village that gets approached by an NGO, are significantly advantaged relative to households in other villages. Although no absolute barrier exists for engaging in the transaction of information, the limited exposure by NGOs presents itself as a barrier that undermines equitable access to such information. The technical expertise offered by NGOs, and the visual confidence attained through pilot projects, are essential catalysts for SRI adoption. A prominent comment among the respondents who have never practiced SRI, is that they lack the confidence because they have not seen it in action, and have not had the means to learn more about it.

A similar dynamic applies to obtaining information from, or joining, SRI based collectives. In objective terms, there are no discriminative barriers for engaging with, or partaking in, a collective. It is even noted that some collectives include members from multiple villages. A membership fee of around 5,000 riels is typically required; which is overall affordable. Although no direct discriminative barriers exist, there are factors that undermine what would otherwise be equitable access to such collectives. Social distrust is a major factor at play here, and arises from the polarized political affiliation among the Cambodian population. The tensions caused by the polarized political affiliation are remnant from the horrors undergone under the Khmer Rouge regime. This point of politically fueled social distrust is accentuated in the case of CEDAC, where one of the leading members is trying to establish their own political platform. In this case, non-members of collectives that were founded with the aid of CEDAC are distrustful as they perceive these collectives to be politically-affiliated centers.

Further, limitations exist to the equity of implementation of SRI systems. For SRI implementation to be successful, it must occur under a set of enabling conditions. Ultimately, the totality of these conditions is not fulfilled by many rural households. Consequently, not all households have equitable opportunity to implement SRI. This could be due to factors such as lacking space to install irrigation infrastructure, or simply lacking the physical capacity to meet the SRI labor requirements. In one case, it is noted that households located in a community with small plots of land (less than one hectare), have tried to collaborate with one another to install irrigation infrastructure, such as ponds, that extends across neighboring plots; to limit the spatial intrusion on any single plot. These efforts, however, were undermined by the social distrust factor just outlined. The inequity of these enabling conditions, ultimately, is what led to the stark decline in SRI adoption in Takeo.

Whilst SRI's social impact on equity is poor, when successfully implemented, SRI can have a strong positive effect on the empowerment of rural households; although limitations are present. The first direct impact that SRI has on empowerment is with regards to resource self-sufficiency. By being a system that distances itself from the use of agrochemicals, SRI promotes households to be reliant on their own livestock capital to produce organic compost. Assuming a household has the capacity to care for, and house, livestock; producing their own compost enables households to be less dependent on external inputs for developing soil fertility. In turn, by going organic, households are not subject to suffer from the price and availability fluctuations of such inputs, and from the financial burden it causes. Among non-SRI based households, a leading cause of financial stress falls on the need to purchase synthetic fertilizers. Many of such households rely on annual systematic loans to purchase agricultural inputs; because their cashflow is inadequate during key points in the year. Such households are essentially trapped in a continuous cycle of managing debt to sustain their livelihood. Thus, the production of compost with the utilization of a household's own assets, reduces their financial burden, and need to approach external sources. This benefit is further compounded when the consideration is held that SRI also has the potential to boost yields and income (whilst cutting costs); thereby further empowering households financially. This dimension of empowerment, is not only subjected to households who have the capacity to raise livestock. Compost can also be made using organic (plant) waste from production, and from organic material gathered in the proximate environment. Although this is possible in an objective sense, it is noted that the presence of natural flora is decreasing; thereby diminishing the capacity to gather 'wild organic material' for producing compost. Nonetheless, in an enabling environment where a household has the capacity to produce their own compost (either from their own assets, or from the proximate natural environment), this form resource self-reliance is a form of foundational empowerment.

The creation of compost, furthermore, can provide additional benefits that extend beyond just managing soil fertility. When coupled with a bio-gas system; the methane byproduct of the organic decomposition that occurs during compost production, can be used to fuel a gas stove for cooking purposes. This, in turn, further empowers a household as they become more dependent on their own resources, rather than having to gather or purchase firewood for cooking. The capacity to install such a biogas system, however, is determined by a household's financial capital as it is costly. Thus, such a system only really empowers households who can capitalize from their production. Furthermore, as outlined, households must have the capacity to care for the necessary livestock. This is no light feat, as 1 hectare of land requires approximately 15 to 20 tons of compost; which requires approximately nine cattle to produce an adequate supply of dung (in addition to plant material). In turn, this form of empowerment through resource self-sufficiency does not provide benefit to subsistence based households (with limited land and resources), to the same extent as it does to commercial based households.

In this respect, the resource self-sufficiency requirements of SRI may, in turn, dis-empower subsistence based households from implementing the system. This applies not only to the need for the capacity to maintain adequate livestock for compost production, but also to the need to have access to adequate irrigation infrastructure to manage the delicate soil moisture requirements of SRI. Furthermore, the contextual condition of limited labor supply, consequently burdens SRI implementers with the need to be dependent on their own labor-resource. This, therefore, disempowers households with limited capacity to meet these requirements to implement the system. In these circumstances, households either revert to, or continue, the use of machinery to execute the production system. Whilst the use of such machinery provides a burden financially, and disempowers households who are required to operate on debt, it does empower households with the capacity to execute operations with their available (household) labor capacity.

The limitations resulting from labor shortages or limited physical capacity of household members, can be (and is) subdued through the establishment of collectives. Although this is not a direct consequence of the SRI practice in and of itself, these organizations play a vital role for enabling beneficial livelihood outcomes from SRI; and empowering its members. Although the trend is declining due to the transition to machinery, such collectives can (or have in the past) provide labor sharing initiatives. In one case where labor sharing is no longer present in the collective, the female members took it upon themselves to establish an autonomous labor sharing group for single female-headed households. Such labor sharing initiatives, significantly enable households that would otherwise struggle to meet the labor demands. This form of empowerment, in turn, is an effective alternative to utilizing machinery due to labor restrictions. In addition to simply providing additional man-power, such labor sharing initiatives also provide an effective means to disperse skill capacities among the community.

The more significant impact on empowerment by collectives, is when they embody the role of a social enterprise; rather than simply being a platform for information. Two such cases have been identified among the sample of respondents. In both cases, the collectives require a one-time membership fee of around 5,000 riels. In addition to this, shares can be bought from one of these collectives; from which an annual dividend is issued. In this collective, shares are sold for 12.50 USD. The dividends earned from these shares, in turn, provide additional income which strengthens financial security. One household is reported to earn an average of 8,000,000 riels annually from dividends alone. This additional income, in turn, empowers individuals to either: expand their production; seek additional means of income; or make valuable investments into health and education. The issuing of such shares, enables the collective to become a profit-driven social enterprise. In this case, the collective buys (or collects), processes, and sells rice grain. In addition, this collective also provides loans, and facilitates access to: diesel fuel, pre-made compost, and high-quality seeds. Furthermore, these collectives provide the use of assets, such as storage facilities, that would otherwise be difficult to develop for a single household. By engaging in the processing of rice, this collective can empower its members financially by skipping the 'middle-man' along the distribution chain, and thereby achieving a higher price. Furthermore, the issuing of shares enables collectives to hire labor; thereby making aspects of the functioning of the enterprise autonomous from the livelihood requirements of the collective's members.

Members of the collective are also able to process their own crop, and distribute it through the established customer base. An inherit benefit of such collectives, is that they provide a branded standard. This brand, essentially, holds and carries a reputation. Thus, by joining such a collective (and adhering to the standard), households are empowered to sell their grain for a higher price due to the collective brand association. It is via this higher price (coupled with the higher yields and lower costs), which is enabled through the market integration of collectives, that SRI makes its strongest contributions to empowerment. The branded reputation associated with collectives is not only beneficial for market integration, but also for obtaining loans. A household's capacity to obtain loans from microfinance institutions is vastly improved when their production is successful and associated with a reputable collective.

Social Sustainability – Gender Dynamics

Although SRI's empowerment contributions are mainly financial in nature, it is worth noting that empowerment also results in other social dimensions. As mentioned, SRI empowers households to be resource self-sufficient. Additionally, the dismissal of agrochemicals in SRI, empowers households to be more in control of their health. Furthermore, assuming successful implementation, SRI can empower subsistence based households to be less food insecure; and empower commercial based households to become more food secure. Whilst SRI can lead to empowerment via any of the mentioned dimensions, its impact on gender dynamics is less clear-cut.

Among the eleven respondents who still practice SRI, three female-headed households are identified. In these three cases, SRI has led to significant livelihood development; and has empowered these women to become financially secure, and care for their children and sick elderly. In these cases, it is notable that these women are capable of achieving fruitful economic returns, due to the low overhead cost associated with SRI. Although the labor-intensive nature of SRI is a recurring thematic limitation, these three cases demonstrate that it is a barrier that can be overcome by: strong will, dedication, and careful time management. In one case, a household of three members manage 1.5 hectares of land; and in another case a household of four members manage 2 hectares of land. One respondent went so far as to hand dig one of her ponds; with dimensions of 10 meters x 20 meters and 5 meters deep. It is worth noting, however, that these three successful cases each possess two primary enabling conditions. The first of which, is that they are not too old and physically capable of performing the tasks. The second enabling condition is that they owned enough land to capitalize from, and contain the necessary infrastructure (such as a pond, or space for livestock). In turn, due to the capacity to gain financial return, in none of these cases are the women required to engage in multiple livelihood activities, nor are their children required to labor in factories. Rather, the income earned from SRI has enabled these women to expand their current production system; so that all their land is actively in production throughout the year.

Although these women have the physical capacity to perform the tasks, SRI does negatively impact their time-use burden. In all three cases, it is noted that the time-consuming nature of SRI negatively impacts their ability to allocate time for general household duties. The process of preparing the seedlings can take up to twenty days, and planting can take up to thirty days. Considering that these households cultivate two crops in a year, the preparation phase of SRI alone can take up around four months in a year. This burden is extenuated by the fact that these women dedicate any additional time to expanding, and working on, their production system. Ultimately, however, the positive livelihood outcome outweighs the negative impact on their time-use burden. All three women, however, did express a desire to transition to the use of machinery; as this would enable more time to be dedicated towards leisure and other household duties. However, when faced with the trade-off between obtaining high returns with the high time-use burden of SRI, or obtaining lower returns (due to the higher cost of production) with more leisure time; the higher returns of SRI offer a more fruitful livelihood opportunity and these benefits outweigh the costs.

Contrary to the literature reporting cases where female-headed households achieve lower productivity rates, the three highlighted cases from this research's sample demonstrate that both female-headed and male-headed households achieve similar productivity rates. As demonstrated in *Table 5.,* both types of household head obtain an average of around 4,000 kilograms per hectare. Not only did both gendered households achieve similar productivity rates, but the female-headed households in this sample outperformed the male-headed households. The success that these women experience, however, does lead to social tension within the community, that disproportionately ails female headed households. Rather than inciting inspiration, the success of these women (and other successful SRI implementers) leads to jealousy among non-SRI implementers. This dynamic, consequently, results in the theft of crops. Among the sample, these actions are only directed towards female-headed households. Although jealousy

is also directed to successful male-headed SRI households, no cases of theft are reported. Such theft, however, is not only directed to successful female-headed SRI households, but also to struggling subsistence based female-headed households. In one case, it is noted that even an elderly woman, who is struggling to maintain her subsistence production and food supply, was robbed of her cow. This potential for theft, furthermore, hinders the capacity of female-headed households to expand their production. In one case, it is reported that a woman had chosen not to farm fish in her pond, as she feared that it would get consistently stolen.

The need for strong will and determination, in turn, is not only important for meeting SRI's labor requirements, but is also important for persevering through the social tensions that may arise from one's success. Additionally, these characteristics are important for undergoing the initial transition from conventional systems to SRI. This initial transition is a period of great uncertainty, as there is no room for failure. In turn, a key characteristic of these women is that they are all risk takers. Facing risk does not only occur during the initial transition, but happens continuously at each step of expanding production (such as creating a pond). These risks are compounded when a household takes out a loan. Although in these cases, SRI provides substantial financial return, households may at times still require additional capital to develop their system. Obtaining a loan for incorporating a new element into the production system is inherently riskier than taking out a loan to finance a repetition of a previous method (e.g. taking out a loan just to purchase fertilizer); simply because the outcome is unknown.

Although these identified households are achieving good returns on their production, it appears that this success does not surpass the gendered difficulty of obtaining a loan as a single-mother female-headed household. It is noted that because there is no man in the household, micro-finance institutions distrust a woman's capacity to pay off a loan; despite their current level of success. In this circumstance, SRI does not contribute to increased access to external financial capital by women. Once again, strong will and determination are valued characteristics to face these challenges. Additional challenges are faced by women whose SRI production system has failed, or is underperforming in a given year. One such case is noted where an older woman's crop failed due to a shortage of rainfall during the transplantation phase. As the skills obtained through SRI are not transferable, and demand for SRI labor is low, this woman was unable to find work as an agricultural laborer. She is further disadvantaged as men are given preference when hired as labor; namely under the paradigm that they are more physically capable of conducting the necessary tasks. Furthermore, due to her age, she is unable to obtain work as a factory laborer. Her only option, in turn, was to plant a late crop utilizing the conventional method of randomly sowing the seed. Thus, when considering the dynamic impact of SRI on the successful and unsuccessful cases of women-led SRI implementation; it is evident that SRI can result in vastly different livelihood outcomes. Although the increased vulnerability of SRI during the initial transplantation phase may undermine its development value; this defect is countered by its proven potential to empower female-headed households and improve their livelihood outcomes.

Female-Headed Households			Male-Headed Households		
Yield (kg)	Land (ha)	Yield (kg/ha)	Yield (kg)	Land (ha)	Yield (kg/ha)
7000	1.5	4666.67	3000	1	3000
5000	1	5000	1000	0.4	2500
4000	1	4000	1500	0.5	3000
			5000	1	5000
			1200	0.2	6000
			5000	1	5000
			3000	0.8	3750
			2200	0.3	7333.33
Mean		*4555.56*			*4035.714*

Table 5 – Productivity Rates SRI Implementers: Female-Headed and Male-Headed Households

Regarding male-headed households, there are no notable differences between the way agricultural labor duties are divided between SRI and non-SRI households. Typically, women would either do the transplanting or sowing of seeds, whilst the men would plough the land. Both the men and women will typically aid in efforts during harvest time. Although no prominent difference is noted between the way agricultural tasks are divided between SRI and conventional methods; it is worth noting that under a SRI system, the female members are disproportionately affected in terms of their time-use burden. Since women are delegated the task of transplantation, they are disproportionately affected by the increased manual labor requirement of this task (relative to the conventional method of simply sowing the seeds). This negative impact is compounded in the case of subsistence households that are required to engage in additional livelihood strategies. In these circumstances, however, the beneficial livelihood outcomes associated with SRI, are considered by households to outweigh the negative impact on the female member time-use burden.

SRI, furthermore, is not deduced to impact the general gender roles within a household. It is repeatedly reported that the duties at home are considered to be divided equally between the female and male members. Among these tasks, the women would typically care for the children, cook food, and maintain the dwelling; whilst the men would typically do the more intensive tasks such as collecting water. In turn, no differences are noted in the gendered power dynamics between SRI and non-SRI based households. Commonly, households would state that decision making falls equally between the wife and husband of a household. That said, the perspective held by women, is that rural Cambodian villages are still patriarchally dominated. Lastly, SRI has no notable impact on the degree of participation within a household, between its male and female members. Under both systems, both genders will collaborate and divide the tasks so that that they both participate. Furthermore, in circumstances where subsistence households are required to engage in additional livelihood strategies, this responsibility falls both on the female and male members of a household.

Economic Sustainability

SRI Implementers				Non-SRI Implementers			
Yield (kg)	Land (ha)	Yield Productivity (kg/ha)	Price Sold (riel/kg)	Yield (kg)	Land (ha)	Yield Productivity (kg/ha)	Price Sold (riel/kg)
3000	1	3000	1400	400	0.5	800	400
1000	0.4	2500	810	18000	6	3000	
1500	0.5	3000		1000	0.5	2000	1200
700	0.2	3500		700	2	350	900
7000	1.5	4666.67	4000	700	0.2	3500	900
5000	1	5000	4000	1000	0.5	2000	
1200	0.2	6000		2000	0.5	4000	
5000	1	5000	1500	3000	1	3000	
2200	0.3	7333.33		2000	0.7	2857.14	700
5000	1	5000		2000	1	2000	900
4000	1	4000	3500	2000	1	2000	
3000	0.8	3750		1500	1	1500	
3000	0.5	6000		1000	0.5	2000	1000
				5000	1.2	4166.67	700
				500	0.2	2500	
				3000	2	1500	1000
				2000	0.5	4000	
				1000	1	1000	
Mean		*4519.23*	*2535*			*2342.99*	*855.56*
Mode		*5000*	*4000*			*2000*	*900*

Table 6 – Productivity Rates and Price Sold: SRI Implementers, and Non-Implementers

The economic impact of SRI, demonstrates varying provisional results. It has been highlighted that the mean yield productivity rates of SRI systems exceed conventional methods by a factor of 1.9. *Table 6* provides data obtained regarding the varying yield rates, and selling price, achieved by SRI implementers and conventional rice producers. The data in this table contains additional values, where households provided information regarding historical yield rates under an alternate system. Although the difference between the mean yield productivity rates is significant, what is more noteworthy is the difference between the maximum values. Under conventional systems, the highest recorded yield productivity rate from the sample is 4,167 kilograms per hectare. SRI surpassed this with a report of achieving 7,333 kilograms per hectare. This difference demonstrates that under ideal enabling conditions, SRI has the potential to achieve vastly higher productivity rates than conventional methods. Whilst reviewing the maximum rates is of merit, the more pragmatic indicator is a review of the most common productivity rates between the two methods of production. The mode productivity rate of SRI, in turn, is 5,000 kilograms per hectare; whereas the mode rate of conventional systems is 2,000 kilograms per hectare. Thus, the mode productivity rate of SRI systems exceeds conventional systems by a factor of 2.5. It is thereby evident that SRI can, and does, provide significantly higher productivity rates than conventional systems.

Comparing the average productivity rates between the two categories of producers, however, only provides partial insight; as there are vast asset (such as the size of land) and contextual differences (such as the presence of village-wide water infrastructure) between the households. Thus, a more insightful comparison, comes from reviewing the change in yield rates resulting from a transition to SRI from conventional systems, on the same plot of land. From the sample, this data is obtained for four households who are currently implementing SRI. As demonstrated in *Table 7*; within the same plot of land, SRI does achieve productivity improvements by a factor of at least 2.5.

Conventional Yield Productivity Rate (kg/ha)	SRI Yield Productivity Rate (kg/ha)	Factor of Change
2000	5000	2.5
2000	5000	2.5
1500	4000	2.7
1000	3000	3.0

Table 7 – Change in Productivity in Transition from Conventional Methods to SRI

The higher yield rates achieved under SRI, positively impact the degree of profit. Under such systems, profitability is higher than conventional methods due to the cumulative effect of: higher yield rates, lower production costs, and higher selling prices. It has been outlined that when households implementing SRI establish an independent processing system and distribution network, they achieve significantly higher results. The mean price of SRI rice sold exceeds that of conventional systems by a factor of 3. Although the mean SRI price of 2,535 riels per kilogram is higher than the mean conventional price of 856 riels per kilogram, the mode price illustrates a much more significant difference. The most common price obtained for SRI rice is 4,000 riels per kilogram, whereas the mode price of conventional systems is 900 riels per kilogram. Thus, the most common price obtained by SRI rice surpasses that of conventional systems by a factor of 4.4.

This significantly higher selling price obtained for SRI rice, positively impacts the levels of profit achieved. The positive impact of SRI on profitability is further reinforced by the decrease in associated production costs. To clarify this perspective, the reduction in operating cost can be conceived by considering the foregone costs of conventional methods. Under the conventional utilization of machinery, the overall annual cost of production is said to fluctuate around 500 USD per hectare. Of this amount, approximately 150 to 250 USD accounts for the annual cost of synthetic chemicals per hectare. The remainder accounts for the cost of renting machinery, the fuel used, and in some cases the hired labor. The primary piece of machinery that is typically utilized, is a mechanical plough; which costs annually around 70 to 100 USD per hectare to operate. Harvesting machines are also sometimes used, and their rental cost averages around the same as that of the mechanical plough. The third piece of machinery that is a staple for households who have access to water infrastructure, is a mechanized water pump. No data is obtained, however, regarding the cost of rental/ utilization of water pumps; as this is largely dependent on rainfall patterns and can vary significantly each season. Thus, since SRI does not encourage the use of machinery (except for pumping water), and synthetic chemicals, the implementation of this system can forego a significant portion of the conventional annual operational cost of approximately 500 USD per hectare (essentially the totality of that cost minus the cost of utilizing a water pump).

Although SRI does forego the costs just outlined, there are other costs incurred under the SRI system. For the implementation of SRI to reach maximum potential, it is important to have a form of irrigation

infrastructure and composting system; and a means of processing and distribution. For one hectare of land, the dimensions of a sufficient pond would be around 25 by 28 meters, and 5 meters deep[16]. This is assuming that all the land is distributed as one parcel. Such a pond can be dug by hand if the household is physically able; or be dug by tractors for a cost of 2,000 USD. Coupled with this investment, is the annual operating cost of a mechanized pump. In some circumstances, households can utilize irrigation ditches that are constructed by the government. These ditches are located alongside the main roads that connect the villages; and are constructed in unison with the roads (the material taken out of the ditch is used to structure the road). Households located in proximity to these ditches, in turn, are relieved of the burden of financing their own irrigation infrastructure. Whilst this is a beneficial consequence; it should be noted that in one village some households decided to fill up the ditch, to expand the area of their cultivation land. By doing this, the functioning capacity of these ditches became undermined, and ultimately became inadequate to meet the needs of the rest of the village.

For composting, the infrastructure required can be very minimum – essentially just a box to store the decomposing manure and organic material. Owning livestock does vastly increase a household's capacity to produce compost; however, the cost of maintaining livestock was not ascertained from the sample respondents. A better, but costlier, form of composting infrastructure is a biogas system. Such a system provides multiple benefits as it produces both compost, and gas which can be used as fuel for cooking. Such a system costs 850 USD to construct, and can be done by hiring specialists in the region. Thus, although SRI does yield higher rates of financial return, the enabling infrastructure can be costly. What is important to consider here, however, is that the cost of installing a pond or biogas system is generally a one-time expense. Occasional maintenance costs do apply; however, they do not match the initial investment. Once installed, and the one-time expense is committed, these assets can contribute significantly to positive livelihood outcomes.

The annual operating costs of SRI systems, in turn, consist of: the care of livestock, the use of mechanized pumps, the processing of rice, and its distribution. As mentioned, the operating cost of such pumps and the maintenance of livestock, is unclear. Further, the cost of processing and packaging rice was not ascertained from the sample respondents. This activity is typically done within the SRI-based collective; and can be conducted either by the collaborative contribution of the collective members, or via hired labor. The first means, does not provide an increased financial burden, but does increase a household's time-use burden. Lastly, a unique expense to successful SRI systems pertains to transport. To be successful, SRI implementers cannot rely on the existing merchant distribution network; as they hold no consideration for the higher quality grain mediated by SRI. Thus, SRI-based households are required to establish their own customer base, and formulate their own distribution means. To enable distribution, such households are generally dependent on private transportation services. The cost of transportation is typically around 2.5 USD per 50 kilograms of product; although in some cases the customer will either cover the totality of the cost, or provide a contribution.

Thus, the operating costs of SRI systems remains ambiguous. Nonetheless, the sample cases of current commercial scale implementers all assert, that the after-expense profit is higher than the conventional methods. It should be noted, that these lucrative returns are ultimately only possible if a household relies primarily on their own (unpaid) labor. In none of the cases of successful SRI implementation, did a household state that they are dependent on external labor. If a household were to rely on hired labor, the associated costs increase substantially; and may undermine the rate of profitability. In cases where a household is unable to meet the labor requirements themselves, they typically will opt for the use of machinery. The use of machinery (such as a harvester, or seed spreader), is not only more easily managed by someone who is not in an optimal physical state (such as the aging

[16] Although adequate dimensions can range from 15 by 20 meters, and 3 meters deep – to 35 by 45 meters, and 5 meters deep.

demographic), but is also considered to be cheaper relative to the costs of attaining hired labor. For example, it is stated that the annual hired labor costs associated with harvesting one hectare of land can amount to 150 USD, if all activities are done manually. Contrary, the same can be conducted by a harvester for an annual rental fee of around 75 USD.

Furthermore, when comparing SRI to conventional systems, the paid labor financial burden rests heavily on SRI due to its more tedious planting process. For example, under a conventional system, one person can sow the seeds via the traditional random spreading method on one hectare in four days. Whereas, it may take two people approximately a month to plant one hectare of SRI. Thus, to keep operating costs lower than conventional systems, households are required to be of a physical capacity to perform the duties themselves. As soon as they are required to rely on external labor (for example, due to old age), then the use of machinery with conventional methods becomes more economical and profitable.

Evidently, with suitable enabling elements, SRI can lead to substantial returns that enable livelihood development. If the conditions are met where a household can effectively manage their irrigation water, and natural fertility, SRI results in a healthier crop with larger grains than can be achieved under conventional systems. Furthermore, the use of organic compost contributes to building (and improving) the natural fertility of the soil. This in turn, strengthens the capacity of SRI agricultural plots to maintain long-term yield stability. Contrary, conventional systems that utilize chemical fertilizers undermine the soil's natural long-term capacity to bear plants; as these chemicals kill the microorganisms that are essential to producing humus, and processing nutrients in the soil through the decomposition of organic material (Hemenway, 2009). The culmination of effective water management and natural soil fertility development, enables households to achieve a fruitful and a healthily steady crop throughout the year (i.e. both during the wet and dry season). Where SRI falls short with regards to yield stability, is its increased vulnerability during the initial planting phase that occurs at the start of the rainy season (when water availability is still low due to the prior dry season). Although the elements just outlined strengthen yield stability within a year once the system is running, this vulnerability that exists undermines the capacity for yield stability between years. Thus, as noted, there are cases reported where SRI systems failed due to rainfall shortage during the critical transplantation phase. In such cases, the diminished yield stability resulting from SRI's vulnerability, negatively impacts the livelihood outcomes of these households; as it disrupts their capacity to maintain cashflow that results directly from rice production.

The maintenance of cashflow is a critical element for the economic sustainability of rural households; as most households do not hold savings, and ultimately live from paycheck to paycheck. Thus, the disruption to the ability to maintain cashflow is a serious detriment to the capacity of households to maintain their livelihoods. This issue is compounded, when one factors in the fact that SRI does not provide immediate transferable skills that lead to other employment opportunities. In turn, the SRI associated vulnerability that can result in poor yield stability, and the poor capacity to obtain employment opportunities, are two elements that undermine the economic sustainability of SRI.

These issues, however, are predominantly directed at subsistence-based households; as they typically manage smaller plots of land that limit their capacity to utilize infrastructure such as ponds in an effective way. As outlined prior, a valuable indirect consequence of SRI on commercial-based households, is that the financial return from SRI can be used to reinvest in, and expand, their production system. In these cases, households are consequently not reliant on a single crop, which decreases their livelihood vulnerability. For such households, although SRI on its own may lead to yield instability in a given year, this does not necessarily result in a disruption of overall cashflow; as the household has other crops and assets (such as livestock) that can be capitalized on. Thus, for commercial-based households, SRI can lead to the stability of cashflow if the household reinvests their financial capital in a way that effectively

diversifies their production system; thereby spreading the risk over a variety of different crops, rather than being dependent on one.

The economic sustainability impact of SRI cannot be evaluated solely on its direct and indirect economic outcomes. Rather, for SRI to be economically sustainable it must fulfill the associated conceptual principles (as outlined in *Figure 7.*). The impact of SRI on the social-institutional system varies depending on the dimension being evaluated. SRI as a practice does not undermine institutional systems; rather, the existence of these institutions is critical for its successful implementation. This manifests primarily through the existence of SRI-based collectives, and the presence of SRI-promoting NGOs. The successful implementation of SRI, however, can undermine social dynamics within a community as less-successful households become jealous. This jealousy can lead to theft that is primarily directed at female-headed households; although, female-headed households are targeted regardless of their state of success or disparity. Whilst SRI can undermine the social system in this way, it can also strengthen the social bond between members of SRI collectives. This manifests through the cases of labor sharing initiatives, and the cases where members collaborate to undertake the processing and packaging of the collective's product.

Further, SRI does not undermine the human system; as it can have a positive impact on food security and health. It could be deduced that the manual labor requirements of SRI, may have long term negative impacts on the physical well-being of households who operate their own system. This dynamic, however, is difficult to measure within the scope of this research. What is relevant, however, is that overall, successful SRI implementers agree that the beneficial livelihood outcomes of SRI outweigh the increased physical labor burden. Lastly, this review deduces that SRI does not undermine the environmental system. These dynamics are explored in the coming section pertaining to environmental sustainability.

Environmental Sustainability

The environmental impact of SRI, when implemented effectively, achieves the conceptual goal of maintaining the integrity of ecosystems. Every case of SRI implementation reviewed for this research, managed the natural fertility of the soil via composting. These households, in turn, are able maintain an organic cycle of soil regeneration. By achieving this cycle of resource self-sufficiency, SRI implementing households maintain the regenerative cycle of nutrients in the soil. This, therefore, realizes the principle that the use of renewables should not exceed the rate of regeneration. This principle is also realized with regards to the use of irrigation water. This condition, however, only applies to households who utilize an irrigation catchment basin (such as a pond). Such infrastructure is utilized by both SRI implementers and non-implementers. Comparatively, the intermittent flooding associated with SRI does reduce the stress on water resources; as opposed to the continual flooding that is practiced under conventional methods. The reduction in this stress is deduced from the consistent claim among commercial SRI implementers, that the alternate water management strategy enabled a larger supply of water to be available for alternate crops.

SRI also realizes the condition of substitutability; wherein the use non-renewable synthetic fertilizers are substituted with the use of renewable compost. Additionally, the use of non-renewable fuel (gasoline) is minimized drastically by the reliance on manual labor rather than machinery. This minimization extends across most forms of agricultural machinery. Seed spreading, ploughing, and harvesting machines are substituted by manual labor; whereas mechanized pumps are still utilized by SRI implementers. No manual pumps are noted to be utilized among the sample. This could, in part, be because often a large ditch is used as a catchment basin. Since the depth, and corresponding water level, are not consistent across the entirety of the ditch; the use of a portable (mechanized) pump is more pragmatic. Nonetheless, although non-renewable fuel is still utilized to operate such pumps, the use of fuel is minimized to the maximum limit possible with the available alternative means of performing the

duties typically achieved by machinery. In turn, the rate of fuel use among SRI systems is significantly lower than that of conventional methods.

In one respect, SRI realizes the condition of assimilation; where the rate of waste disposal should not exceed the rate of assimilation. This condition is achieved via the use of organic compost. A composting system, in principle, is a system that centers itself on recycling animal and organic waste. Thus, these forms of waste do not only meet the rate of assimilation, but the assimilation is enhanced via the human intervention of the composting system. The rate of assimilation of the emissions resulting from fuel use, however, could not be measured within the means of this research. Nonetheless, the comparatively lower use of fuel under SRI, can be used to conclude that the rate of emissions assimilation is better than conventional methods.

Thus, by realizing the principles of regeneration, substitutability, and assimilation, it is deduced that SRI as a practice is effective in decoupling environmental stress from economic growth. The substitution of synthetic chemicals, does not only result from the use of compost and its substitution of fertilizers. Rather, the regulated spacing pattern performed under SRI, enables more effective manual weeding; as the weeds grow in the spaces between the rice plants, rather than among them. This enhanced capacity to perform manual weeding, in turn, substitutes the need to utilize synthetic herbicide. Thus, the sparse cropping intensity of SRI provides not only benefits for the rate of nutrient uptake per plant, but also contributes to a reduction in the need to apply synthetic chemicals. When coupled with agroecological techniques, the implementation of SRI can also reduce the need for synthetic pesticides. The two model cases reviewed in the sample, both demonstrated the use of specific plants that are known to repel pests. These plants include the use of garlic, along with other fragrant herbs. This application, however, is not a result that is directly associated with SRI. Under an independent SRI system, the rice monocrop does little to ward off pests. Under commercial SRI systems, however, the resulting income can be (and is) utilized to make production reinvestments. It is via these investments that SRI can indirectly impact the substitutability of synthetic pesticides with the use of natural pest-repelling plants. An additional indirect positive environmental impact of SRI, arises with the use of biogas systems. Since these systems also produce fuel for cooking-stoves, they reduce the need to forage for fire wood in the proximate environment. This, in turn, reduces the stress on the natural local lumber resource.

Lastly, the ecological footprint resulting from the land use pattern associated with SRI, is deduced to pose no significant negative environmental impact. Aside from the housing structure, and the few pieces of machinery that may be owned, the land use pattern of SRI is generally natural. For example, the ponds needed for irrigation, are simply composed of a hole in the ground; no concrete reinforcement is used, nor is any plastic lining used. Furthermore, the use of such ponds typically provides the environmental benefit of hosting ecological diversity. This results from the incorporation of fish in the ponds; which not only provide the benefit of being a food source, but also contribute to the natural soil fertility (that is in direct proximity to the pond) with their excrement.

Discussion

SRI Sustainability Overview

SRI Impact Score - Subsistence Based Households

	Scoring Scheme	Significant Negative Impact	Minor Negative Impact	No Significant Impact	Minor Positive Impact	Significant Positive Impact	**Score**
		-2	-1	0	+1	+2	
Social Sustainability	*Food Security - Availability*					X	**2**
	Food Security - Access			X			**0**
	Food Security - Utilization			X			**0**
	Health and Well-Being					X	**2**
	Shelter			X			**0**
	Equitable Access				X		**1**
	Empowerment					X	**2**
	Gender - Division of Labor		X				**-1**
	Gender - Roles			X			**0**
	Gender - Participation			X			**0**
	Gender- Power Dynamics			X			**0**
	Gender - Access to Assets			X			**0**
Economic Systainability	*Land Productivity*					X	**2**
	Yield Stability	X					**-2**
	Profitability			X			**0**
	Maintain Cashflow			X			**0**
	Employment Opportunities			X			**0**
	Not Undermine Soc. System				X		**1**
	Not Undermine Human System					X	**2**
	Not Undermine Env. System				X		**1**
Environmental Sustainability	*Land Use Pattern*			X			**0**
	Cropping Pattern			X			**0**
	Soil Fertility Management					X	**2**
	Pest Management			X			**0**
	Regeneration				X		**1**
	Substitutability				X		**1**
	Assimilation				X		**1**
Total							**15**
Sustainability Index							**0.64**

Table 8 – SRI Impact Score: Subsistence Households

SRI Impact Score - Commercial Based Households

	Scoring Scheme	Significant Negative Impact	Minor Negative Impact	No Significant Impact	Minor Positive Impact	Significant Positive Impact	Score
		-2	-1	0	+1	+2	
Social Sustainability	*Food Security - Availability*					X	**2**
	Food Security - Access				X		**1**
	Food Security - Utilization				X		**1**
	Health and Well-Being					X	**2**
	Shelter			X			**0**
	Equitable Access				X		**1**
	Empowerment					X	**2**
	Gender - Division of Labor		X				**-1**
	Gender - Roles			X			**0**
	Gender - Participation			X			**0**
	Gender- Power Dynamics			X			**0**
	Gender - Access to Assets				X		**1**
Economic Systainability	*Land Productivity*					X	**2**
	Yield Stability				X		**1**
	Profitability					X	**2**
	Maintain Cashflow				X		**1**
	Employment Opportunities			X			**0**
	Not Undermine Soc. System				X		**1**
	Not Undermine Human System					X	**2**
	Not Undermine Env. System					X	**2**
Environmental Sustainability	*Land Use Pattern*					X	**2**
	Cropping Pattern					X	**2**
	Soil Fertility Management					X	**2**
	Pest Management			X			**0**
	Regeneration					X	**2**
	Substitutability					X	**2**
	Assimilation					X	**2**
Total							**32**
Sustainability Index							**0.80**

Table 9 – SRI Impact Score: Commercial Based Households

Thus far, the results presented demonstrate heterogeneous dynamics between SRI, and its direct and indirect impacts on livelihoods. To gain an overall generalized perspective of the sustainability implications, an index scheme is presented that scores the sustainability impacts of SRI on subsistence and commercial based households.

The outcome of the index illustrates that the overall sustainability impact of SRI is positive in the context of both subsistence and commercial-based households (as illustrated in *Table 8. And Table 9.*). With a score of 0.80, the sustainability impact of SRI is more significant for households operating on a commercial scale. Whilst the impact is still positive for subsistence households, its score of 0.64 illustrates that this impact is less significant. With the consideration that an index score of 0.5 represents the condition of 'no significant impact', it is deduced that the overall positive sustainability impact of SRI on

subsistence-based households is minor. This, however, pertains to the totality of the three pillars that comprise sustainable development. Although the overall sustainability score is minor for subsistence-based households, the social outcome for such household is still of significant merit. This pertains primarily to the consequential reduction in the degree of food insecurity for such households. This element, ultimately relates to the capacity to survive. Thus, whilst the economic and environmental impact of SRI in the context of subsistence-based households is minor; the beneficial livelihood outcome of reduced food insecurity holds enough merit to validate the developmental potential of SRI.

These two indices, however, only provide a conglomerative score of the overall sustainability impact of SRI on the two categories of households. To better understand how the impacts differ between subsistence and commercial households; *Figures 13, 14, and 15* illustrate the social, economic, and environmental impacts respectively. The social sustainability impact of SRI, is more significant for commercial households in terms of: food access, food utilization, and gendered access to assets. For subsistence households, there is no significant impact on these three variables from SRI. This is essentially a consequence of the inadequate capacity to capitalize from their production.

The difference in the capacity to capitalize from production systems is illustrated under the economic sustainability scoring. Although the impact on productivity rates is significant for both commercial and subsistence-based households; there is no significant impact on profitability or maintenance of cashflow for subsistence households. This arises as a consequence of the limited size of land utilized for production. Further, SRI is considered to provide a significant negative impact on the yield stability for subsistence households. This is a consequence of the limited capacity for such households to implement irrigation infrastructure on their land; which in turn, increases their vulnerability to weather variability. This variable is scored as receiving a significant negative impact, due to the severe negative livelihood (and survival) implications that result from a failed crop. Then; although the impacts on the social and human system are deduced to be even between the two categories of households (where the impacts do not undermine these systems), SRI does 'not undermine the environmental system' to a greater degree in the context of commercial households.

This last point is illustrated by reviewing the environmental sustainability implications of SRI on both household categories. Aside from the impact on soil fertility and pest management (which possess an equal degree of impact between the two household categories), SRI provides a more significant impact on the remaining variables for commercial households. The lack of impact on the land-use and cropping pattern of subsistence households, is a consequence of the limited associated land available to work with, and its resulting poor capitalization potential. Thus, for commercial households, SRI has a more positive impact on rate of regeneration, assimilation, and substitutability; due to the enhanced capacity to spatially incorporate the features necessary for composting and irrigation management.

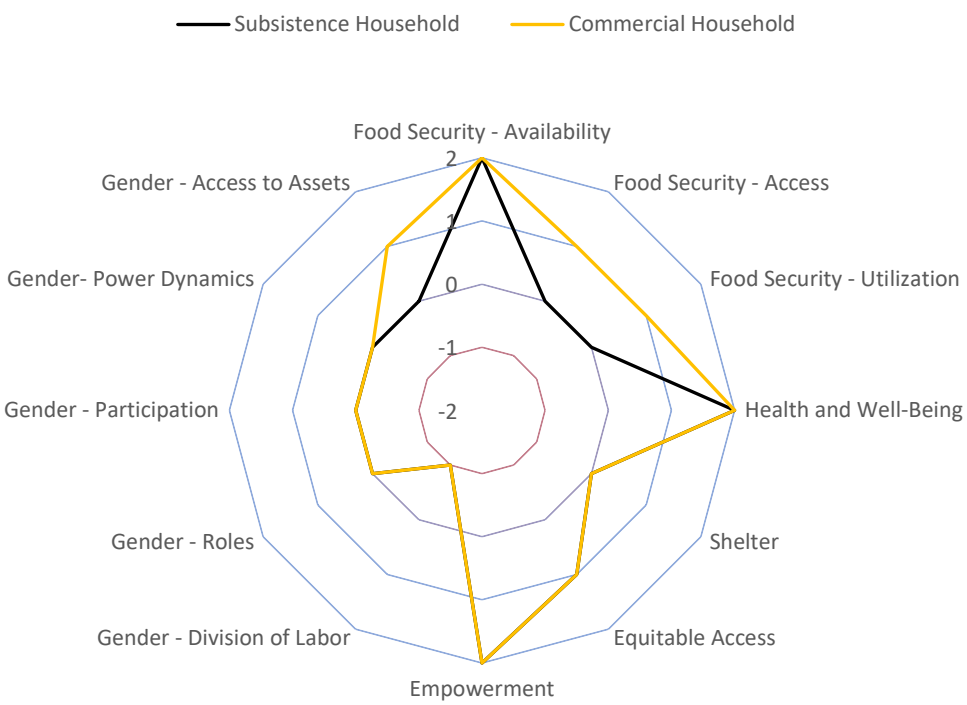


Figure 13 – SRI Social Sustainability Scoring

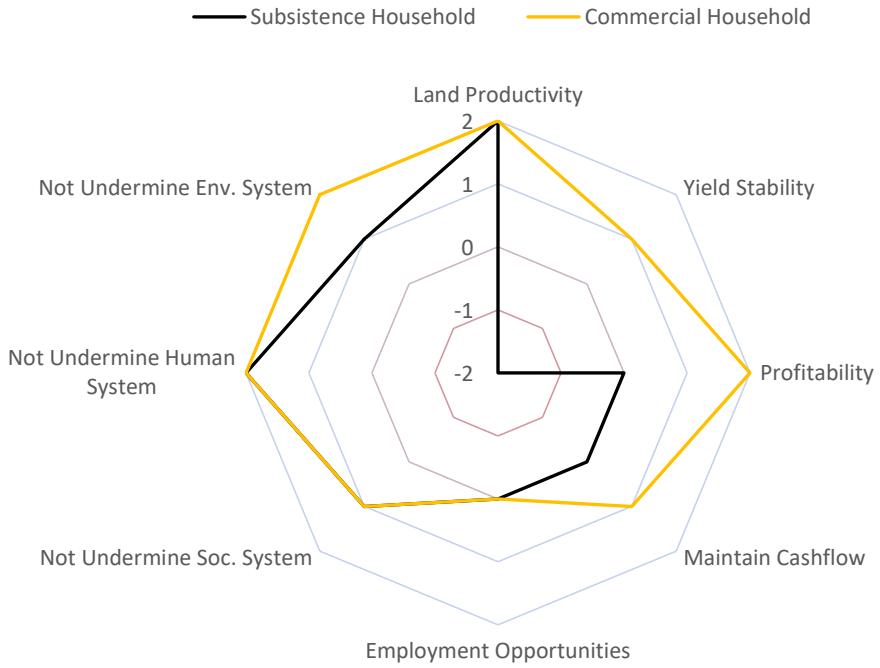


Figure 14 – SRI Economic Sustainability Scoring

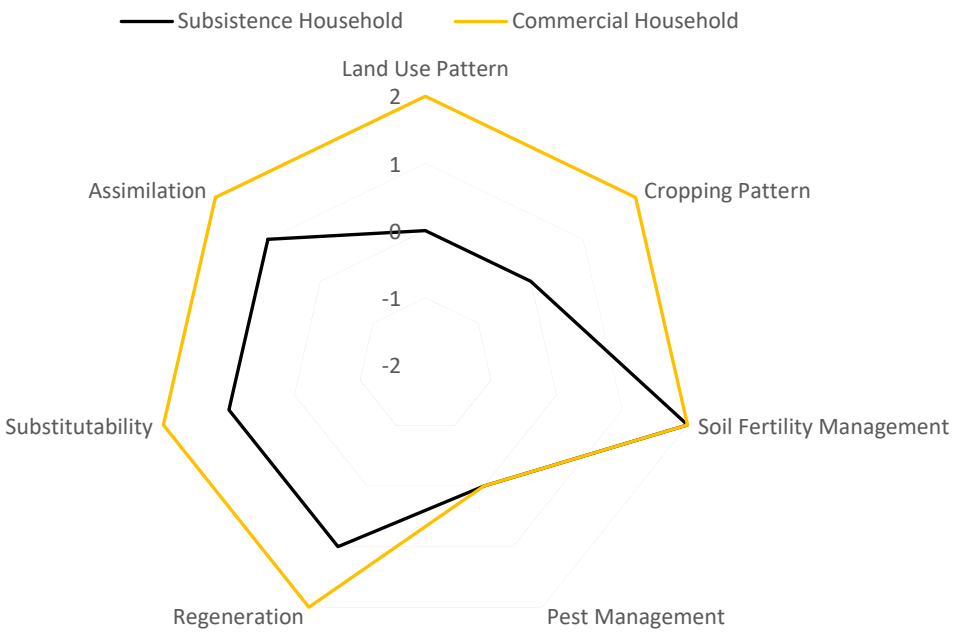


Figure 15 – SRI Environmental Sustainability Scoring

Conditionality of SRI Success

Objectively, SRI has the capacity to result in livelihood development, which achieves an overall positive sustainability impact. The capacity to realize these results, however, is highly conditional. As has been deduced through this report; SRI only yields positive livelihood and sustainability results when a set of enabling conditions are met (as listed in *Table 10.*). For the implementation of SRI to be successful, there needs to be an adequate supply of water. For this condition to be met, in turn, there needs to be enough rainfall, and an appropriate form of irrigation infrastructure to manage it. Consequently, an adequate size of land is needed to contain the supporting components of a SRI system. This is needed not only for irrigation infrastructure, but also for the care of livestock that contribute to the supply of compost. The size of land needed can be reduced if a form of irrigation infrastructure exists in proximity to the household's property. This could include roadside ditches, ponds, lakes, or groundwater pumps. In addition to enabling the existence of the supporting components of SRI, an adequate size of land is also imperative for shifting the potential of SRI from simply enabling survival and a reduction in food insecurity, to enabling the development of production systems in a financially lucrative way.

Furthermore, the existing merchant distribution network serving conventional rice producers cannot be relied upon to meet the expected prices for higher quality SRI rice. In turn, it is essential that alternative distribution systems exist to enable the capitalization from SRI. NGO's have been critical in establishing the initial connections between SRI producers and relevant buyers. In the case of CEDAC, the NGO sometimes acts as a middle man that purchases grain and organic vegetables directly from SRI producers. One household is reported to earn approximately 250 USD per month from such an arrangement. In most cases, however, CEDAC does not continue this arrangement, and SRI producers are expected to establish their own network base. Nonetheless, the initial connections facilitated by CEDAC, have been imperative in building confidence among new SRI adopters that a market exists for higher quality grain. NGOs are essential not only for establishing initial distribution networks, but they also serve

the critical role of providing the initial distribution of relevant information. Such information is critical for informing rural communities about the potential benefits of SRI, and how the system is to be implemented.

Lastly, a fundamental condition for the success of SRI, is that the manual labor requirements of the system can be met. Although this condition would typically imply an adequate supply of labor, it has been deduced through this research that at the current average wage rates, SRI would not be financially lucrative if labor were to be hired. Consequently, for this condition to be met, it is imperative that members of implementing households have an adequate physical capacity to perform the needed tasks.

Conditions for SRI Success
Physical Capacity of Household or Labor Supply
Accessibility of Relevant Information
Rainfall During Transplantation Phase
Effective Irrigation Infrastructure
Means of Producing Compost
Adequate Size of Land
Distribution Network

Table 10 – Conditions for SRI Success

Reasons for SRI Failure

The conditional dependence for SRI's success, is ultimately the determining factor that has led to the stark decline in SRI implementation in recent years. For SRI to effectively be implemented, every one of the outlined conditions must be met. These requirements, however, are not met amongst a growing number of households in rural Takeo. For every one of the variables, at least one case exists among the sample where the condition is not met. The most overarching factor that has led to the failure of SRI, is the reduction in rainfall volume in recent years. The higher degree of vulnerability to water shortage of SRI, serves both as a deterrent for some non-implementers who have heard of the practice, and has led to failed systems among some implementers. Water scarcity, however, does not only result from inconsistent and reduced rainfall patterns. It is also noted to arise as a result from competing interests in available water bodies. This occurs, for example, in a case where larger companies obtain exclusive rights to proximate lakes to produce ice. Thus, although in such cases water is not necessarily scarce in an objective sense, agricultural households still experience water scarcity as they have no (or limited) access to existing water bodies.

The following relevant variable, is the inadequate physical capacity of households to perform the necessitated tasks. This element has been compromised by the increasing emergence, and development, of the manufacturing and construction industries in the region. This phenomenon has led not only to the reduction in the availability of wage labor, but has also led to the reduction in the available supply of physically capable labor within households. As these industries attract an increasing number of young physically able bodies, the rural agricultural sector is becoming dominated by an aging population that are increasingly becoming less able to meet the necessitated physical requirements of labor intensive agriculture.

Next, the limited scope of NGO engagement in the region, is another determining factor for the failure of SRI. Essentially, these NGOs failed to effectively distribute information pertaining to SRI evenly across the province. This has compromised the rate of SRI adoption; as many households lack confidence in its developmental potential, simply because they have never seen it be implemented and have never

learned about what it entails. The limited scope of NGO engagement, furthermore, has also negatively impacted the potential to establish alternative distribution networks. There are cases noted where households who learned about SRI independently and had implemented it, reverted to conventional methods because they were unable to obtain lucrative financial returns due to a low selling price.

Lastly, a prominent issue is the fragmentation of land. This point essentially rests on the reported trend, that land owners have sold off (and still are selling off) portions of their land for additional income. This, in turn, has led to the fragmentation of land; resulting in an increasing number of households who own land that is only adequate for subsistence purposes. This impacts the capacity for households to effectively possess the supporting elements necessary for the successful implementation of SRI. This issue is complicated further by the fact that many households do not own land as a single parcel. This, in turn, complicates the ability of households to effectively position irrigation infrastructure, and distribute compost from where it is produced.

SRI and its Role in Development

Despite experiencing a decline in its implementation, the positive livelihood outcomes resulting from SRI are unquestionable. This is particularly apparent among the two model cases studied; Ms. Lay Guecsim and Mr. Ros Mao. Among these two cases, however, it is important to note that SRI is not a dominant element in the production system. Although SRI can result in beneficial outcomes, there are two factors that undermine its suitability for comprising the entirety of a production system. The first, and most relevant, is its vulnerability during the early phase of production. This vulnerability is a significant dimension that can undermine the whole cropping cycle. In turn, SRI is not a system that is to be relied upon solely. The second factor pertains to conceptual issues that arise from mono-cropping. Namely, that a mono-crop is more vulnerable to pests; thereby further contributing to its vulnerability.

Thus, it is important to understand what role that SRI can, and does, play in development. The immediate contributive role that SRI plays is that it is an effective means of increasing cashflow that can be used for livelihood development (such as education and health), and for the development of production systems. The best outcomes, as observed in these two cases, result when SRI is coupled with a boarder integrative system. The mono-crop nature of the sole implementation of SRI, for example, increases the risk of pest infiltration. When coupled with natural means of pest management, however, the system intrinsically becomes less vulnerable. Additionally, when integrated in a broader system, this further reduces the risk of depending on a single crop, and enables households to continue generating income during (and in between) the rice growing cycle.

Then, a critical role for SRI in development, is the resulting empowerment of women and vulnerable / underperforming households. The lower relative operational costs of SRI, provides an effective means to secure livelihood performance for households (and particularly women) who struggle to meet the financial obligations of conventional systems. Further, SRI can play an important role in empowering households to become less food insecure.

The Future of SRI Under Current Contextual Conditions

Consequential of the ageing agricultural demographic phenomenon, and the will to free up more time, there is a desire among SRI implementers (even the model cases) to transition towards the use of machinery. A consistent misconception noted among most of the respondents, is that SRI and the overall use of machinery are two independent, and opposing, production methods. In cases where a prior implementation of SRI failed due to an inability to meet the labor demands, households would abandon

all aspects of the SRI methodology, and simply implement the conventional method of: random sowing, agrichemical application, and the use of machinery.

The roles that machinery play in a production system, however, do not necessarily relate to the aspects of SRI that make it successful. The success of SRI derives from the: organic regeneration of the soil, the spacing of plants (which enhances the nutrient uptake per plant), and the careful management of soil moisture. The application of machinery, however, does not relate to these aspects. Rather, incorporating machinery provides the utilitarian benefit of enhancing the process of: ploughing, planting, and harvesting. Thus, it is conceivable that machinery can be applied to serve these tasks, without compromising the elements that make SRI successful. The only aspect of SRI that cannot be substituted by an alternative method, is the process of weeding. This process, however, is more pragmatic under a SRI system, as the spacing between the plants enables easy access. Thus, it is plausible to consider a situation where all other labor demanding tasks are substituted by the use of machinery, and only the weeding be done manually. Such a system would still enable SRI to reach its potential, whilst reducing the physical, and temporal, stress on the members of a household.

The existing forms of machinery currently applied under conventional methods, however, are only suitable to be utilised for the ploughing and harvesting process under SRI. Conventional sowing machines (such as a seed blower), are not transferable as they do not enable the crop spacing requirements of SRI. Thus, to substitute the manual planting process, alternative (non-conventional) forms of machinery are required. Such machinery already exists in three forms. First, there exists a machine that trenches the soil in rows, as a means of preparation prior to the actual planting. Second, machines exist that sow seeds in rows (as opposed to randomly spreading the seeds in all directions). Third, a transplanting machine exists that automatically plans young seedlings in rows.

Despite the desire to transition to machinery, current SRI implementers have not done so due to the associated costs. They all claim that it is not economically viable, and do not wish to run the risk of expanding their debt. Furthermore, in the case of the SRI appropriate planting machines; these are only noted to be accessible in one of the sample communes; being the Trapeang Thum Khang Cheung commune, located in the Tram Kak district. In this location, an NGO is noted to operate that offers the rental of the transplanting machine, for 50 USD per hectare. The NGO will only transport the machine to the village, however, if 20 to 30 households undergo the rental service. This condition, in turn, compromises the accessibility of the machine, if only a few households wish to use it.

Thus, under the current conditions, where the need for machinery will increase as the population continues to age, it is important that the availability and accessibility of appropriate machinery be improved. This can be addressed in a few ways. First, government subsidies could be applied to reduce the cost of machinery; thereby enhancing its accessibility with regards of the financial capacity of households. Second, SRI collectives can be enhanced and strengthened, by expanding their membership base; to enable adequate demand to justify the transportation of specific machinery to rural areas. If the membership base of a collective crosses over multiple villages, then collectives themselves could hire such machinery (as opposed to a single village being a designated customer cluster); as their membership base would warrant the condition set by the NGO for transportation. In such a scenario, the collective would require a means to transport the machinery independently between its member households. Thirdly, if the prior two approaches are combined; it is conceivable that if subsidies are adequately applied, collectives may be able to afford the purchase of such machinery. In this scenario, the collective could earn additional income by offering rental services.

Social and Economic Sustainability vs. Environmental Sustainability

The contextual conditions that are leading to a trend that necessitates the utilization of machinery, brings up a conceptual conundrum. In this situation, environmental sustainability is being foregone for the development of social and economic elements. This brings to question whether development initiatives realistically, and pragmatically, should always meet the criteria of achieving holistic sustainable development. In the case of SRI; if the current contextual conditions are not addressed, the mechanized implementation of SRI will not achieve holistic sustainable development in the future. Conceptually, this change in status may discredit the value of SRI to promote development. Nonetheless, the trade-off emerges out of the need to sustain livelihoods. The social and economic benefits provided by SRI to households, are significant and should not be dismissed. Ultimately, sustaining the lives of people is the priority of development.

Although the social and economic dimensions essentially remain to be priorities, ignoring the environmental impact could result in long-run consequences; as the social and economic spheres are ultimately dependent on the environmental sphere. In turn, this ultimately becomes a temporal issue, where environmental sustainability could be foregone in the short-run; as the mechanized version of SRI provides a temporary solution. In the long-run, however, for development to be sustainably effective, environmental sustainability considerations must be accounted for. This, in turn, necessitates systemic reform.

Need for Systemic Reform

It is evident, that the current contextual trends are necessitating changes to SRI that diminish its sustainability impact. Although SRI implementation can be adjusted to meet the changing contextual needs (by foregoing some of its sustainability impact), these adjustments only provide a limited symptomatic solution. These adjustments simply enable an aging population to continue their livelihoods; but does little to address the broader contextual issues that are necessitating the adjustment. Thus, it is pertinent that efforts are made to revive the agricultural sector in its entirety. Such efforts require systemic reform, and would enable the sustainable transformation of the sector.

First, the ageing rural demographic issue should be addressed. A factor that is reinforcing this trend, is that there does not exist any form of public pension or retirement coverage. Offering such services, in conjunction with subsidized retirement housing, could catalyze a demographic turnover in the sector. Social services such as these, would incentivise the ageing population to sell their properties, thereby opening a gap in the market to be filled by a younger demographic.

Second, the Cambodian government needs to incentivise the adoption of agricultural production systems, by the younger demographic. This can be done by either aiding in the start-up process, or by aiding in market dimensions to make the ventures more profitable and financially attractive (or doing both). To aid in the start-up process, the government can subsidise the cost of purchasing property, or provide special loans for individuals within an appropriate age range. Additionally, they can undertake ventures to enhance the accessibility and availability of relevant assets and resources. Schemes can be created to distribute organic compost, for those unable to produce it. The government can also aid in the construction of storage structures. Such structures would enable households to store their crop, until they judge the market price to be more favorable. Further, if the sector is to develop, there is an urgent need to advance the irrigation infrastructure network. At the very least, every village should have access to a roadside catchment ditch. Eventually, it would be better if a series of constructed canals are created, which would enable the mobility of water to drought-prone areas.

Third, if SRI is to achieve it its developmental impact potential, the government must address the issue of land fragmentation. Efforts should be directed towards conglomerating land; so that adequate

plots exist to host the necessary components of SRI. Such efforts would drastically change the sector's production landscape; thereby enabling agricultural households to capitalize off their production and progress socio-economically, rather than simply surviving. Such efforts can be executed: with incentive strategies, such as special loans for smallholders who wish to purchase neighboring land; or by legal arrangements, where land cannot be fragmented further than a minimum size.

Fourth, as touched on in the second point; for the rice market to flourish, the distribution and processing network must be revised. A first step could be to promote the construction and use of storage structures. This would enable households to hold more bargaining power under the existing merchant distribution system. In addition, it would be beneficial to promote that the processing of crops, occurs within the country by local citizens (rather than have that industry manifest in Vietnam or Thailand). This effort should be a part of a larger effort to localise the distribution and processing system in its totality. An additional effort could be to promote the functioning of social enterprises/ collectives. It is evident from this review, that such enterprises are beneficial for providing a means for collaborative effort, and entrepreneurial ingenuity.

Lastly, the mechanism for knowledge distribution and exposure needs to be revised. Despite the collaborative efforts between the government and NGOs during the start of the century, many rural households have not been exposed to the practice. Consequently, there remains to be misconceptions and mistrust regarding SRI among this demographic.

Concluding Remarks

From this research, it is apparent that SRI has the potential to yield substantial beneficial livelihood outcomes. These benefits, however, are mainly derived indirectly, and are dependent on coexisting aspects; such as collectives and NGOs. If implemented effectively, these aspects can yield reinforcing benefits; such as from biogas systems, and irrigation ponds that contain fish. SRI on its own, can yield direct benefits; particularly on income generation and food security. These benefits, in turn, enable the potential for the empowerment of those facing disparity. Although there are trade-offs associated with SRI (such as effects on time-use-burden), it is apparent that the benefits outweigh the incurred costs.

The scope of these benefits, however, is highly dependent on the extent to which the enabling conditions are met. Under these conditions, it is deduced that SRI can achieve a holistic sustainability impact. This point, however, is more conceptual than it is pragmatic. Increasingly, the conditions that propagate the success of SRI are not being met. Thus, if the potential social, economic, and environmental benefits of SRI are to be achieved, the agricultural industry in its entirety should be revised. The state of development and empowerment achieved by the two model cases, provide an indicative measure of the value of SRI, and why it should not be abandoned.

A recent alternate initiative in the country, is the establishment of a private standard for the production of organic rice (*the Sustainable Rice Platform)*. For further research, it would be worthy to review the livelihood and sustainability impact of such an initiative; and to evaluate the comparative impacts between such a standard and SRI. Such initiatives may prove to be beneficial in geographic areas that are not suitable for SRI (such as flood-prone regions). This review hypothesises, however, that the contextual limitations that led to the diminished implementation of SRI in recent years, would also hinder the success of private standard initiatives. Lastly, this review encourages further study in the developmental impact of SRI. Particularly, it would be of merit to develop comprehensive balance sheets of SRI production systems. This would provide more in-depth insight to the financial functionality of SRI.

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