修　士　論　文

Adoption of System of Rice Intensification in a Larger Production Scale

大規模経営における System of Rice Intensification の導入

東京大学　新領域創成科学研究科

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主査________________________________

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Chapter 1 Introduction

1.1. Background of This Study

Agriculture was transformed forever when the Green Revolution of the 1960s and beyond took over the world. An impressive increase in yield was achieved, particularly in eastern Asia, and the global food supply eventually exceeded the total demand of the world population. However, the Green Revolution depended on the promotion of high-input, intensive agriculture, meaning that the beneficiaries of the Revolution were restricted to those who were relatively well-off in the first place and had the capacity to access modern resources[1]. On the other hand, poorer farmers who could not afford such investment were left further behind in the global rural development process. Naturally in the narrative of development, the next step was to devise and deliver an innovation to those marginalized by the Green Revolution for them to achieve similar economic gains, but no grand transformation that match the scale of the Green Revolution has been developed to this day.

Along the continuous stream of dogged efforts to improve the livelihood of the poor farmers emerged a small innovation called the System of Rice Intensification (SRI), a collection of rice production techniques strategically put together to increase the rice yield while reducing the amount of resource inputs. Farmers who successfully adopt SRI have more rice to consume or sell, while their cost of

[1] Modern resources promoted by the Green Revolution include improved seeds, irrigation, chemical fertilizer, pesticides, and mechanization of the production process (Noltze et al., 2012).

production is reduced, ultimately improving their income. This method of rice production has disseminated among poor rice farmers across the world through top-down efforts of various academic, nongovernmental, governmental, and international organizations, especially in Asia and Africa. Major international institutions such as the World Bank Institute, International Rice Research Institute (IRRI), and NGOs like Oxfam have all shown support for the SRI movement. The degree of acceptance of SRI has varied greatly from one country to another, resulting in stagnation to endorsement at a national scale. However, adoption of SRI has been limited to small-scale farmers, often holding rice farms of 1 ha or less.

However, few studies have scrutinized the SRI as a phenomenon from a social perspective. Much of the academic interest in SRI has been from an agronomic perspective, mainly concerned with technical assessment of changes in on yield and cost, and the agronomic mechanism and impact of SRI on the rice plant. Because SRI is a set of agronomic techniques, this trend makes sense - the impact of SRI on yield and cost depends on location-specific environmental and socioeconomic conditions of the adopting farmer. More fundamentally, agronomic mechanism of SRI is yet to be fully understood, which has been a puzzle that researchers have been diligently working on solving.

Advocates of SRI agree that it is one of many alternatives to the Green Revolution, and as one of the strategies for the rural development, as evidenced by the wide array of institutional support for SRI. Essentially, the idea that SRI benefits the rural poor and can advance rural development, even if slightly, have been an unchallenged notion thus far on the ground of successful increase in yield and decrease in costs.

1.2. Purpose of This Study

How does the social impact of a technology change with an increase in farm size? When a technology diffused among small-scale farmers is applied to a larger farming operation, how does it affect the rural development? Using the case of SRI dissemination in the Dominican Republic and comparing the impact with cases in other SRI-adopting countries such as in Asia where the background is different, the study attempts to draw some implications and contribute to the understanding of the role of SRI in rural development.

Ultimately, the author argues that the SRI in larger scale than conventional SRI does affect rural development, but it also creates an unintended effect in widening a pre-existing inequality involved in managing a larger scale of rice production.

1.3. Research Method for This Study

This study investigated the research question through an analysis of the past literature and a field survey. Details on both methods are as follows.

1.3.1. Literature Review

Considerable amount of literature has been published on SRI, mostly from Asia and Africa. The literature was compiled and analyzed for the quantified impacts of SRI on production costs and income compared to conventional methods. However, few studies have focused beyond the agronomic perspective of the practice and looked into the social impact of SRI with respect to the rural development.

Literature on the Dominican rice production is few. In light of this, papers by Winston E. Marte from the Kyushu University have been of particular value. Using a detailed report on cost structure of rice production by Marte, this study also conducted a cost analysis of rice production under SRI method, and drew some conclusions.

1.3.2. Field Survey

The author of this study traveled to the Dominican Republic from August 5, 2012 to August 16 and surveyed the rice fields and conducted interviews with farmers, relevant organizations, and government personnel involved in SRI and the Dominican rice sector. The author contacted the director of the Inter-American Institute for Cooperation in Agriculture (IICA), an international organization engaged in rural development across the Americas, which kindly arranged for numerous visits across the country in the span of two weeks. Interviews were mainly concerned with the farm management and the comparison between SRI method and conventional method of rice production.

1.4. Structure of the Thesis

The structure of this paper is as follows. Chapter two discusses system of rice intensification as a whole – why farmers and other actors are interested in it, and what the benefits and costs of the method are. Drawing on experiences from Asia and Africa where SRI development has been relatively more robust, the chapter also discusses the Latin American experience of the rice production thus far. Chapter three discusses the Dominican Republic in some detail with respect to the rice sector. It provides an overview of the rice production in the country, as well as the current issues that the sector faces.

Chapter four discusses the key findings based on the field survey from August 2012, and explains the steps taken to conduct the cost analysis. Chapter five discusses the results, and makes an argument for how SRI can both advance and hinder rural development in the Dominican Republic. Finally, chapter six concludes this study with some afterthought and suggests future studies that would further strengthen the findings from this study.

Chapter 2 System of Rice Intensification for Latin America

2.1. Brief Overview of SRI

System of rice intensification (SRI) is a set of agronomic principles. According to the global SRI home page hosted by the Cornell International Institute for Food, Agriculture and Development, its methodology is grounded upon four main principles (CIIFAD, 2012):

- Early, quick and healthy plant establishment
- Reduced plant density
- Improved soil conditions through enrichment with organic matter
- Reduced and controlled water application

SRI was founded by Father Laulanie in Madagascar after over 20 years of observations of local farmers and personal trials and errors in growing rice. Originally sent from France as a missionary, he soon believed that increasing the production of rice, a major diet in Madagascar, is the key solution to alleviating the local poverty that he witnessed. As he realized that modernized, high-resource-input method of rice production was difficult to access for poor farmers, Laulanie sought to find an improved production method that can accommodate poor farmers, which eventually culminated as the "system of rice intensification (SRI)" in 1983. While few people have paid attention initially, SRI later gained momentum when it was discovered by Norman Uphoff, a professor from the Cornell University, who became convinced of the merits of SRI after 5 years of trials in Madagascar.

The individual principles that constitute SRI were far from groundbreaking. They have been discovered and practiced by farmers on their own in various parts of the world. For example, principles similar to that of SRI have been invented and practiced by some farmers in the past in Japan (Horie et al., 2005). A rice production method similar to SRI called “gaja planting system” has also been invented in Tamil Nadu region of India about a century ago (J-SRI, 2011). However, while the SRI principles have been practiced individually in the past, SRI is nonetheless innovative in a marketing sense, strategically combining these technical elements into a “package”.

Essentially, this “package” of techniques can be applied virtually anywhere by flexibly modifying its principles to suit the site-specific conditions. In this regard, it is similar to the industrial projects that Albert Hirschman has described in The Principle of the Hiding Hand. Transferable from one place to another, SRI looks as if it could be indiscriminately applied anywhere, despite site-specific uncertainties and difficulties which could get in the way of SRI from turning into a successful venture. SRI is made attractive to the farmers by development institutions through both the “pseudo-imitation” technique and “pseudo-comprehensive-program” technique, and makes naturally risk-averting and conservative farmers take risk instead and try SRI. And most importantly, SRI has often yielded success for the farmers who took that risk[2].

2.2. Motivations for Dissemination of SRI

2.2.1. Benefits for Farmers

Farmers are willing to modify their agricultural practices if such changes in their behaviors guarantee greater benefit, e.g. an increased yield. Likewise, motivations for the farmers to adopt SRI lie in its potential for an increased yield, and to save

[2] Arguably, SRI is in disagreement with Hirschman’s claim that agricultural projects are less suited to the operations of the Hiding Hand.

cost of production. Table 2.1 shows the increase in yield reported by SRI literature. With successful adoption of SRI, some farmers are able to have more rice for them to consume, while others are able to increase their income by selling more rice.

Table 2.1 Yield Increase by SRI in Various Countries (from Uphoff, 2004[3])

Country	Average Comparison Yield (ton/ha)	Average SRI Yield (ton/ha)
Bangladesh	4.9	6.3
Cambodia	2.7	4.8
China	10.9	12.4
Cuba	4.3	7.4
Gambia	2.3	7.1
India	4.0	8.0
Indonesia	5.0	7.4
Madagascar	2.6	7.2
Myanmar	2.0	5.4
Nepal	4.2	8.5
Philippines	3.0	6.0
Sierra Leone	2.5	5.3
Sri Lanka	3.6	7.8

Saving cost is another major motivation for farmers. Table 2.2 shows the amount of cost saved by farmers, as reported in the literature. Various input resources like seedlings, fertilizers, pesticides, and water are all conserved if SRI practices are adopted. Seedlings are the most obviously conserved resource in SRI, because seedlings are transplanted only one at a time and at a wider spacing, instead of a typical 4~5 seedlings at a time in conventional practices. The amount of fertilizers and pesticides used are often reduced because SRI practice encourages less chemical inputs. Irrigation water is another resource in production in which major saving is observed by SRI. Because SRI aims to aerate the soil, paddy field is

[3] The list of average and SRI yields are compiled from various sources by Uphoff (2004).

irrigated intermittently rather than ponding the field throughout the growth of rice[4]. The global SRI homepage claims the water savings can reach up to 50%; however, SRI literature have shown a high variation in the water savings, depending on the conditions of the experiments. A series of experiment in Mali successfully increased the rice yield, but the participants were only able to reduce irrigation water use by 10%, due to both the characteristics of irrigation water distribution system which made water control by individual farmers impossible, and the fear of farmers for desiccation of their crop, given the dry and inherently water-scarce nature of the area, further hindered the attempt to reduce water use (Styger, 2010). On the other extreme, Sharif (2011) achieved irrigation water savings by 70% in Punjab region of Pakistan, and Turmel et al. (2010) reported farmer savings ranging from 71% to 86% by simply shifting from daily flooding of the paddy field to irrigation once or twice a week.

Table 2.2 Cost reduction for each factors in rice production

Production factor	% Saved	Source
Irrigation water	10~86%	Styger, 2010; Turmel, 2010
Herbicide	50~95%	Sato, 2006; Tech, 2004
Pesticide	50.00%	Sato, 2006
Fertilizer	17~53%	Wakimoto, 2010; Tech, 2004
Seed	34~90%	Ly, 2012; Adusumilli, 2010
Labor	-91~49%	Tech, 2004; Ly, 2012
Production cost	-15~40%	Ly, 2012; Styger, 2010

Non-agronomic benefits of SRI have also been observed. The author travelled to Luang Prabang Province in northern Laos in July 2011 to visit farmers practicing SRI. The author met a group of farmers satisfied with SRI, who happily claimed that extra income generated by SRI will be used to finance education for their

[4] SRI may be possible with upland rice which does not grow in ponded condition, but the discussion here will assume lowland rice.

children[5]. In addition, the provincial government who was keen to increase rice production in the area has promised a development of irrigation infrastructure in exchange for the farmer adoption of SRI. In another case, Wakimoto and Yamaji (2010) found that farmers were more willing to experiment and make innovations with their rice production practices after they adopted SRI, suggesting that SRI may have some cognitive benefits for the farmers' managerial decision-making.

2.2.2. Problems with SRI

In spite of all the benefits, there are several difficulties associated with SRI. First is the psychological issue; many farmers are initially reluctant to try SRI. Rice is planted earlier in SRI than in a conventional method, meaning that the plant looks considerably weaker and vulnerable than conventionally planted rice at an initial stage. Furthermore, SRI method does not pond the paddy field, which makes farmers nervous for fear of desiccation of the plants, especially for those who have limited access to water supply. As a result, farmers are often reluctant to volunteer themselves to try SRI, and even the brave farmers in the community who are willing to try SRI typically face opposition from their spouse. Upon facing the opportunity to try SRI, the farmers (or their spouse) essentially exhibit a risk-avoiding, "safety-first" mentality[6], where they would rather trust the production method they are accustomed to and count on the stability of the resultant yield, rather than to take a radical departure from their conventional practice and risk the expected yield.

Second difficulty is a technical difficulty, in which more labor is required initially. Because the paddy is not ponded, more weed grows invariably during the growth stage of the rice. As a result, more labor is required to remove the weed, regardless

[5] This is significant, because farmers in this area typically studied only up to 1st or 2nd grade

[6] James Scott discusses this in his book, *The Moral Economy of the Peasant.*

of whether it is removed manually, with a weeder, or with chemicals. More labor is also required for water management, since SRI practice uses intermittent irrigation instead of ponding; therefore, the farmer must operate the water gate and irrigate more frequently. However, studies have also shown that labor can decrease with SRI[7].

Third difficulty is agronomic, in which the great variance in the growth of the plant grown is observed under the SRI method. Since SRI rice depend more on soil moisture content for water resource for growth at intermittent irrigation stage, variance in soil moisture directly affects the growth of the plant, and some tillers inevitably grow insufficiently. Therefore, precise field leveling becomes very important for even distribution of water. A field survey was conducted in Indonesia in a field size 42.1m x 32.4m, divided into 520 units of 2.62m^2 blocks, and yield and deviation in elevation from the average elevation were measured. The survey revealed that there was a strong positive correlation between yield and elevation, where the maximum yield measured was 9.3 ton/ha, while the minimum was nearly half the maximum at 4.8 ton/ha (Sato, 2010).

Fourth difficulty is institutional - the lack of support from certain segments of academia. This stems largely from the fact that the mechanisms of SRI have not been sufficiently explained, and the criticisms from the opposing view was strong particularly in the early years of SRI dissemination (Sheehy et al., 2004; Sinclair and Cassman, 2004). However, it has since become weaker, as major institutions such as the World Bank Institute and International Rice Research Institution, which initially rejected SRI, began to endorse the method.

Final difficulty is economic. Due to conflicts with other incentives available to the farmers, their attention may be diverted away from SRI, and perhaps other methods of improving rice production. For example, rice farmers on the outskirt of Vientiane, the capital of Laos, were presented an opportunity to try SRI in early

[7] e. g. Sato (2006), Ly et al. (2012).

2000, but ultimately rejected the method altogether. Because they lived close to the capital, the farmers decided they were economically better off going into the town for other work than to adopt SRI method with increased labor requirements (for weeding and water control).

2.2.3. Motivations beyond the Farmer Level

As discussed in the first chapter, researchers and institutions are motivated to introduce SRI to the rice farmers because it is seen as the antithesis[8] of the Green Revolution, providing a low-cost and low-input opportunity to improve their livelihood. For example, the fact that the Green Revolution was beyond the reach of most farmers in Cambodia has served as a great incentive for dissemination of SRI (Ly et al., 2012).

Another major motivation for non-farmers in the SRI narrative is mitigation of the impact on climate change from rice production. Intermittent irrigation instead of ponding the paddy means that soil is aerated, and as a result, the amount of greenhouse gas (i.e. methane) from paddy fields decreases. For this reason, SRI is expected to help reduce the impact of rice production on the climate change (Swaminathan and Kesavan, 2012).

Increasing water scarcity, whose causes are diverse and location specific, is another incentive to introduce SRI. Water scarcity may occur due to various causes, not just limited to the aforementioned climate change but also include decreasing available quantity, decreasing quality, malfunctioning of irrigation systems, and increased competitions for the resource (Bouman et al, 2007). Because SRI method reduces total irrigation water use through intermittent irrigation, it also makes rice production more well-adapted and compatible in areas where water is becoming

[8] SRI is considered the antithesis to Green Revolution in terms of the ideals and the concept, though the degree of global impact and acceptance is hardly comparable.

increasingly scarce and its availability increasingly unbalanced, as water is expected to become increasingly scarce (Basu, 2012).

The impact of SRI in reducing greenhouse gas and water use is likely to have a greater impact if it is applied at a larger scale. This adaptation of a larger-scale SRI has been in the interest of researchers (e.g. Sharif, 2011). In theory, it is possible to adopt SRI in a larger scale because SRI principles are scale-neutral, but no such attempts have been made by the farmers and trials have only been done by researchers.

2.3. Current Trends in SRI

2.3.1. Overall Trend in SRI

Table 2.3 shows the year in which SRI was introduced to each country. After SRI was discussed at an academic conference in Indonesia in 1999, the method has steadily been introduced to other countries for a trial. However, not all countries have kept up with the dissemination efforts. Because of the combination of problems described earlier, SRI has been stalled or even abandoned in some areas. Case in point is Madagascar; despite being the country of origin for SRI, the method has barely survived in the country while it has seen significant adoption elsewhere. As described earlier, the initial trials in Laos was also unsuccessful. However, SRI has spread significantly in the country in recent years, albeit in the more rural areas in the northern part of the country.

Table 2.3 List of countries that introduced SRI

Year	Asia	Africa	Latin America
1999	China, Indonesia	Madagascar	
2000	Bangladesh Myanmar Cambodia Nepal India Philippines Laos Sri Lanka Thailand	The Gambia	Cuba
2001		Sierra Leone	
2002		Benin	Peru
2003		Guinea, Mozambique, Senegal	
2004	Pakistan, Vietnam		
2005 2006	Bhutan, Iran, Iraq	Burkina Faso, Zambia	
2007	Afghanistan	Mali	Brazil
2008	Japan	Egypt, Ghana, Rwanda	Costa Rica, Ecuador
2009	Malaysia, Timor Leste		Colombia
2010	DPRK	Kenya	Haiti, Panama
2011	South Korea, Taiwan	Tanzania	Colombia
2012		Burundi, Niger, Nigeria, Togo	Haiti Panama

As table 2.3 shows, Asia has been the most active region in adopting SRI. Many of the countries that have taken up SRI in its early stages of global dissemination has kept up with the practice since, and SRI has also become endorsed by the national government in places like Vietnam and Indonesia. Much of the major rice producers in eastern Asia, such as China, Thailand, and Cambodia, has conducted trials with SRI within the first couple of years from the conference, and they have sustained their engagement with SRI since.

The adoption of SRI in Africa has been slower than in SRI. This may be due to relative difference in the importance of rice, as many African countries also consume maize and other cereals. Another reason may be the presence of other ongoing efforts in the rice sector, most notably the invention and dissemination of NERICA. Nonetheless, African countries have shown considerable interest in SRI over the years.

2.3.2. SRI in Latin America

While production and consumption of rice is most often closely associated with Asia, rice is a nonetheless a major crop in Latin America also[9]. According to FAO (2003), rice is grown in 26 states, producing over 22 million tons of paddy rice per year. Rice is also an important part of the diet, both nutritionally and culturally, for the states in the region. While other grains such as maize and wheat are also consumed in large quantity, rice also forms an important part of the local cuisine in many states in the region. Essentially, rice sector forms an important part of an agricultural development narrative in these countries.

Latin American involvement in SRI movement has been slower than in Asia and Africa. While countries in Asia and Africa have steadily experimented with SRI over the years, most Latin American states have failed to experiment with SRI until 2007, by which 16 countries in Asia and 10 countries in Africa has already conducted at least a trial. However, to this day, substantial SRI activities in Latin America are nearly nonexistent.

A notable exception to the Latin American trend in SRI has been the ongoing effort in Cuba. Cuba has been one of the earliest countries in the world to experience

[9] In this paper, the term “Latin America” will be broadly defined as all states located in Central America, South America, and the Caribbean.

SRI, whose first trial in the country dates back to 2000. Cuban diffusion effort continues to this day, and its principles are now being applied to sugar cane, one of the most economically and symbolically important crop in the country. However, the extent of diffusion of SRI has been limited, and is difficult to call it successful. Peru is another notable exception in Latin American experience with SRI, which has conducted its first trial in 2002. Unlike Cuba, Peruvian SRI experience emobides the SRI narrative in Latin America as a whole, and little have been reported from the country since the initial trials in early 2000s. Despite this, SRI have now reached Brazil, Costa Rica, Ecuador, Colombia, Haiti, Panama, and the Dominican Republic, in addition to Cuba and Peru.

Three major difficulties are identified in SRI efforts specific to Latin America: slow progress, little to no institutional support, and relative distance from the global SRI movement.

The first obstacle is the slow progress in dissemination of SRI throughout Latin America. Rice is produced in many of the countries in the area, and like the rest of the world, many of the rice farmers are subsistence farmers. Socioeconomically, they are likely to benefit from adopting SRI, at least in theory. More opportunities for farmers to learn about and experiment with SRI should be provided in order for them to increase yield and income.

The second obstacle in Latin American context is the relative lack of institutional support in SRI dissemination. While government bodies related to agriculture have lent institutional support in respective countries, the scale of support from institutions is far smaller than that of other countries successful with SRI, especially in Asia. International institutions like World Bank, World Bank Institute, and Oxfam have played a key role in supporting SRI in Southeast Asia and in Africa, yet such organizations have not lent similar support in Latin America.

The third and final major obstacle is the relative isolation from the rest of the SRI community in Asia and Africa. This may be due to the fact that most Latin

American countries speak Spanish. For whatever reason, there have been few communications between Latin American SRI community and that of Asia and Africa. However, Latin American countries have held conferences amongst themselves to collaborate and share knowledge on SRI, such as a conference held in Cuba in 2008 (Uphoff, 2008), and another conference was held in 2011 in Costa Rica

Chapter 3 Dominican Rice Sector

3.1. Overview of the Dominican Republic and Its Rice Sector

Figure 3.1 shows the location of the Dominican Republic, while figure 3.2 shows the map of the Dominican Republic and the major rice production areas within. While the climate of the country is mostly tropical, there is nonetheless great diversity in geography. Precipitation ranges from dry areas with as little as 350 mm of annual rainfall to wet area with as much as 2,740 mm of rainfall. Accordingly, landscapes vary from dry desert-like area in the south and the northwest with poor soils to lowland forests to mountainous, high altitude area.

Figure 3.1 Map of the Caribbean Sea

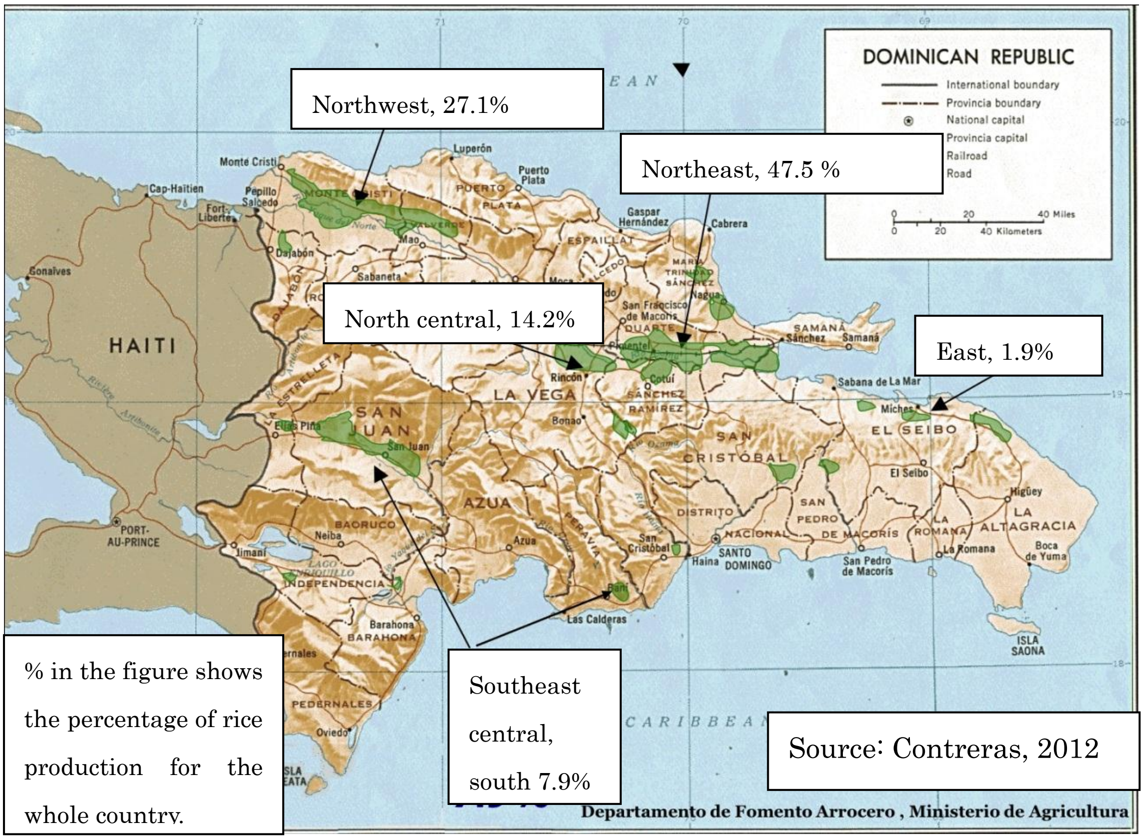

Figure 3.2 Map of the Dominican Republic and the major rice area

The Dominican Republic is a more developed country than many other SRI countries[10]. The country today is relatively urbanized, where 47% of the 9.4 million people in the country live in the ten largest urban areas in the country. 67.5% of total GDP and 63.1% of the total labor force is involved in service-related occupations. Agriculture has been in decline, however; today, the agricultural sector forms 11.5% of total GDP, and 14.6% of total labor force. By contrast, the sector formed 20% of the total GDP and 45% of overall employment in the 1980s (Bravo-Ureta and Pinheiro, 1997). Major crops are sugar cane, coffee, tobacco, banana, and rice.

The rice sector forms a significant part of the country's agricultural activities, and rice alone forms 0.5% of the country's GDP (Marte, 2012). There are over 30,000 rice

10 See appendix A and B for comparison.

farmers in the country, and over 250,000 people in total are engaged in work related to rice production (Contreras, 2012). Today, 178,000 ha of rice are planted. According to FAO, the country has been self-sufficient in supplying rice through domestic production, producing 780,820 tons of paddy rice, and with little need to import rice from abroad compared to the total quantity produced. On the other hand, the price of rice in the Dominican Republic is high, especially compared to the rest of Latin America. As of 2009, the price of rice in the Dominican Republic has gone as high as 815 US $ per ton, significantly higher than the rest of the Latin America and the United States, whose price ranged from 169.4 $/ton to 529.9 $/ton (Pocasangre, 2011).

National average size of rice field per farmer is significantly larger in the Dominican Republic at 4.3 ha (Marte, 2012) than countries in Asia[11] and Africa, suggesting that a successful adoption of SRI in the Dominican Republic could mean that SRI is being applied in a larger area of production.

Due to the tropical climate, rice is grown all year in the country. Rice is typically cultivated twice a year, though three productions in a year are also possible. Rice is planted by both direct seeding and transplanting, most commonly in January~February and in July~August. Because of the climate favorable for year-round production, one paddy from next is often planted at a different timing. Pests are very few, and no large animals or birds exist in the country which could threaten the rice production.

There are two types of rice farmers in the country - those who have access to an irrigation scheme and those who do not. The latter type is landless peasants, both Dominican and Haitians, who practice slash-and-burn agriculture and depend on rainfall for irrigation (Laba et al., 1997). The other type is farmers who either own land or borrow land from the government, with accessed to gravitational irrigation

[11] For example, average cultivation area per family is 0.7 ha in China (農林水産省, 2011), and 1.6 ha in Laos (JICA, 2005).

infrastructures. This paper concerns with the latter type, which is the dominant group of rice farmers.

The Dominican agriculture has a dual structure system. On one hand is *latifundos*, or a large-scale farmers who produce export crops such as sugar and tobacco, while on the other is a smaller peasants that produce crops for domestic consumption. Most of the agricultural land is owned by the state-run Dominican Agrarian Institute (Bravo-Ureta and Pinheiro, 1997). For an example, 70% of the farmers interviewed in a study by Marte (2012) obtained land through a government allocation program, while 11.7% owned land through purchase and another 9.5% inherited from parents or relatives. Farmers who farm the land provided by the government have only the right to grow crops and cannot use the land for any other purposes, as they do not own the land.

3.2. Current Issues in the Dominican Rice Sector

3.2.1. Land Productivity

Rice productivity in the country is low. According to FAO (2012), yield in the Dominican Republic has ranged in between 3 to 5 ton/ha from year to year, while another statistics source (Kyushu University, 2012) showed that the yield of Dominican rice farmers were 3.1 ton/ha as of 2011. By comparison, the yield in the United States has been well above 7 ton/ha and over 6 tons/ha in Japan in the past decade. It is clearly possible that the Dominican rice farms have not yet realized its maximum potential of productivity.

3.2.2. Labor Productivity

As described earlier, a considerable degree of industrial development has taken place in the Dominican Republic over the last several decades, but it also meant that labor force in agriculture steadily shrank in size, creating a labor scarcity in the agricultural sector by the 1980s (Grasmuck, 1982). Such a trajectory of national development is not unique; for example, Japan has experienced a similar drop in labor availability during its period of economic growth in 1960s to 1980s (Murugaboopathi et al., 1992). However, while the Japanese rice sector has responded to depleting labor force with mechanization of rice production and post-harvest operations, the Dominican farmers have responded with exploitation of cheap foreign labor, i.e. the Haitian migrant workers. Because Haitian laborers are better off working jobs unwanted by the Dominican nationals than to stay in poor and underdeveloped Haiti, Haitians are both cheap and docile. As a result, absolute exploitation of labor has become the norm in Dominican agriculture, rather than to increase the productivity (Grasmuck, 1982).

3.2.3. Environmental Impact

Certain practices from rice production have adversely affected the environment. As a result, water quality downstream has suffered. For example, Laba *et al.* (1997) notes that unsustainable agricultural practices along the Yuna River, the biggest rice production area in the country, has led to siltation and pollution of the downstream mangrove forests and aquatic resources. Application of fertilizers also affect the quality of the local environment, in particular the water quality. Table 3.1 shows the recommended input amount of fertilizers in several countries. Fertilizers are clearly applied in relatively large quantity in the Dominican Republic. However, rice farming alone cannot be faulted for adverse environmental impact, as production of other crops may affect the environment negatively as well.

Table 3.1 Recommended application of N fertilizers

Country	Region	kg/ha	Source
Dominican Rep.	Northeast	80-120	Contreras, 2012
Dominican Rep.	Northwest	120-145	Contreras, 2012
Dominican Rep.	Southeast	120-140	Contreras, 2012
India	Andhra Pradesh	60-90	Tandon, 1989 (detail unknown)
India	Orissa	50-75	Tandon, 1989 (detail unknown)
India	Punjab	125-150	Tandon, 1989 (detail unknown)
India	Tamil Nadu	75-100	Tandon, 1989 (detail unknown)
Japan	National	68 (actual amount applied)	Kondo et al., 2009
United States	Mississippi	202	Walker and Street, 2003

Another key issue is lack of maintenance of drainage canals. Irrigation and drainage canals are well-developed with concrete. However, there is a clear difference in the way the irrigation canals and drainage canals are managed – the former is clean while the latter is littered with trash. This is because the responsibility over the management of drainage canals is not clearly defined in the country, due to disagreements between the water user group and the institution responsible for water distribution[12]. As a result, the quality of outflowing water may be further degraded by the time it is returned to rivers.

3.2.4. Political Issues

Human Development Index (HDI) and Gross Domestic Product (GDP) per capita measured by purchasing power parity (PPP) are two indicators of national

[12] This is a finding from my survey in August 2012.

development. Specifically, HDI is a measure of human development, while GDP is a measure of economic development. Appendix A and B show a list of SRI-experienced countries with their most recent HDI rankings, as well as the GDP and their rankings. Interestingly, the Dominican Republic is one of the lowest-ranked countries in Latin America, yet ranks higher than most other SRI-experienced countries in Asia and Africa. The Dominican Republic is a unique case in context of SRI, arguably further ahead in the trajectory of national development.

A major impact of the Green Revolution was that the growth in rice production exceeded growth in human population, thus lowering prices of rice. While this benefitted rice consumers, including poor consumers such as the rural landless and urban laborers, low price ironically put the livelihood of rice farmers under threat (Bouman et al., 2007).

A major turning point for the Dominican rice sector has been the free trade agreement commonly known as CAFTA-DR [13] that was signed between the Dominican Republic, the United States, and five Central American countries of Costa Rica, Nicaragua, El Salvador, Honduras, Honduras, and Guatemala. Covering a broad range of commodities, the free trade agreement removes tariffs on US exports either immediately or gradually, including rice. Having agreed to the terms in 2004, the Dominican Republic will remove the 23.3% tariff on rice imported from the United States in 20 years from the year of agreement. However, much concern has been raised for the impacts of CAFTA-DR, as it has been feared that opening the market to imported rice would undermine the sector, creating unemployment from those who are unable to compete with cheap imported rice, ultimately widening inequality and making poverty more extreme (Jurenas, 2006). Thus, the most urgent task in the current Dominican rice sector is to swiftly implement measures to make

[13] The expected impact of this free-trade agreement on the Dominican economy overall is beyond the scope of this paper, and therefore will not be discussed here.

rice sector more competitive with foreign rice through a combination of technical innovations and strategic implementation of appropriate policies.

The agreement over free trade agreement with the United States has threatened the country's rice sector. Marte (2012) has identified a set of economic and agronomic strategies to mitigate the impact from imported rice. Agronomic strategies include land leveling, use of quality rice seeds, increasing rice yield, and change in rice variety and planting system. In this context, SRI can also be viewed as one of the means to mitigate the impact from CAFTA-DR.

Chapter 4 Cost Analysis and Field Survey

4.1. Development of the SRI Movement in the Dominican Republic

4.1.1. Institutional Dissemination of SRI

Dominican experience with SRI began when Inter-American Institute for Cooperation in Agriculture (IICA)[14] took notice of the cultivation method. IICA viewed the merits of SRI as a potentially effective agronomic mean to mitigate the impact of CAFTA-DR on the domestic rice sector. This is a distinctly different motivation for SRI, which is introduced either to improve the quality of farmer livelihood, increase rice production, or typically, both.

In 2011, IICA invited Erika Styger from Cornell University, one of the central figures in worldwide dissemination of SRI, for a seminar and demonstration on its benefits and methods. The same year, IICA organized information sessions in major rice production areas of the country to recruit farmers willing to test the method. According to Juan Arthur, one of the key figures within IICA in SRI project, finding farmers willing to try was not difficult due to photographic and video evidences of successful increase in yield by SRI from other countries. This is in stark contrast with previous experiences in disseminating SRI elsewhere, in which farmers were often initially reluctant to try SRI.

[14] IICA is an international organization that has an office in 34 states in the Americas. The institution provides technical cooperation and specialized knowledge to promote agricultural and rural development in each member states, working closely with the ministries of agriculture.

4.1.2. Participation in SRI Trials

Figure 4.1 shows the geographic distribution of farmers who experimented with SRI thus far. Trials started in 2011, with farmers in seven different locations. While much diffusion of agronomic techniques begin typically by demonstrations on experimental plot, it is interesting that first trials were done *on farmer plots by the farmers* in the Dominican Republic.

Figure 4.1 Location of SRI trials in 2011 and 2012

Another important characteristic of the Dominican trials is that the location of trials encompasses various natural conditions, ranging from the area with arid climate, poor soils, and poor water availability, to areas with abundant rain and organically rich soils. By experimenting under diverse environmental conditions, the Dominican SRI experience is expected to produce diverse results and provide various insights.

Three universities have initiated agronomic SRI studies (orange font in figure 4.1). Universidad Autonoma de Santo Domingo, an agricultural university in Santo

Domingo (the capital), was schedule to initiate an irrigation experiment in the fall of 2012, comparing ponding condition with drip irrigation for SRI. A graduate student at ITESIL in Dajabon, a town located on the border with Haiti, was conducting an experiment on SRI for his master thesis, comparing SRI with conventional rice production. The author was told that another student from Earth University in Costa Rica is to start an experiment at the University ISA in Santiago in fall of 2012, but the detail of the experiment was not known at the time of the author's visit.

Agrofrontera is a non-governmental organization (NGO) whose aim is to improve both the environment and the economic prosperity of the farmers through improvement in farming systems. It has shown an interest in SRI, and have conducted a test trial of SRI in comparison with conventional and IPM (integrated pest management) methods of rice production.

4.1.3. Characteristics of SRI-Adopting Farmers

The author interviewed farmers as well as Agrofrontera, which works closely with the farmers, on the structure of farm management among the Dominican rice farmers. Table 4.2 shows the summary of the interview results from both the farmers themselves and institutional personnel associated with rice farming. It must be noted that a small population of poor rice farmers who depend on rain-fed farming also exists, but they are excluded from the table as they are characteristically beyond the scope of this paper. As a result, the table summarizes rice farmers with access to irrigation only.

Table 4.1 Characteristics of the Dominican rice farmers

Scale	Small	Middle	Large
Categorical Definition	<2.5 ha	2.5~8 ha	> 8 ha
	Government assistance		Private access to equipment and mills
Other Workforce	Animals		Machines
Decision Makers	Male house head		
Laborers	Haitian laborers		
Crops	Rice only; crop rotation with beans in south		
Water Source	Gravitational irrigation		

A combination of few important characteristics distinguishes the Dominican rice farmers. First, managerial decisions in the Dominican Republic are made by male head alone. In fact, when the author inquired as to whether the farmer's wife is involved in any decision-making process, both the farmer and the accompanying IICA staff laughed at the idea. This is congruous with patriarchal structure of gender relations called *machismo* ("machoism" in English) that is commonly observed in Latin American communities, and certainly not limited only to agrarian communities.

Second characteristic is that, while decision-making is in the hands of the Dominican male farmer, the actual work carried out under the decisions are done by Haitian migrant laborers. The Haitians are highly specialized; some Haitian handles the task of seeding exclusively, while others do only the weeding work, while yet another group is specialized in application of fertilizers, and so on. Haitians are employed by rice farmers of all production scale, from small to large.

Third characteristic is that, rice farmers grow rice exclusively. Access to machinery is available in the country, but this is limited to farmers with larger scale of production. The machines available are tractors, harvesters, and laser technology for land leveling. Individual farmers do not own the machinery. Instead, the owner of the machine provides the machinery service to the farmers. However, the specific cost of utilizing machinery is not available to the author.

4.2. Progress in the Dominican Republic

4.2.1. Improved Productivity

Initial experiments across the country yielded positive results. For example, Fabio Diasa of Hacienda Estrella yielded 11.6 ton/ha of rice with SRI method. In another SRI experiment in Bajo Yuna[15], yield went up from 2 ton/ha to 6 ton/ha. The feeling of satisfaction with improved productivity was also shared by Manuel Sanchez, the head of the Dominican office of IICA, to a point that he even claimed that 20 ton/ha may be possible with SRI in the Dominican Republic once the method is adjusted to the Dominican conditions.

Not all results ended up with a better yield. Another farmer in Bajo Yuna, claimed that the productivity did not improve upon his initial SRI test. However, he was able to reduce the cost by 25%, and thus happy enough with the method that he was willing to try it again while recommending the method to his neighbors.

4.2.2. Reduction of Production Cost

The uniquely Dominican question to ask is, can SRI save the Dominican rice production from the perils of the free-trade agreement by sufficiently lowering the cost?

Table 4.1 shows the national average cost in rice production, as provided by Freddy Contreras of IDIAF (Instituto Dominicano de Investigaciones Agropecuarias y Forestales; The Dominican Institute of Agricultural and Forestry

[15] Bajo Yuna is a lowland area in the northeastern part of the Dominican Republic, known for the greatest area of rice production in the country. In recent years, rice paddies in the area have been reorganized under the government initiative to increase the individual paddy size.

Research). According to the figure, the greatest cost factor in the Dominican rice production is the fertilizer.

Table 4.2 National average cost of rice production (from Contreras, 2012)

(Unit in Dominican dollars)

Soil preparation	312.1	11.9%
Seeds	214.95	8.2%
Fertilizers	652.02	24.8%
Agrichemicals	279.71	10.6%
Labor forces	200.64	7.6%
Harvest	276.83	10.5%
Others	399.28	15.2%
Interests & insurance	296.69	11.3%
sum	2632.22	100.00%

Winston Marte, a former Ph.D student from the Dominican Republic who studied at the Kyushu University, has also had same problem awareness as IICA towards the CAFTA-DR, and focused his research on identifying strategies to mitigate the adverse impact of the free-trade agreement on the Dominican rice sector (Marte, 2009; 2011; 2012). In a paper he published in 2012, Marte conducted a survey on rice production cost, yield, sale price, and revenue with rice farmers from northwestern region of the Dominican Republic, a second-largest rice-producing region in the country. Using his detailed cost structure, this study conducted a cost analysis of the impact of SRI. Marte's survey results were utilized here on the ground that both the total cost of rice production (table 4.2) and the weight of the cost factors (table 4.3) relative to each other are in general agreement.

Table 4.3 Rice production cost(in USD) in Northwestern Dominican Rep. (Marte, 2012)[16]

Item	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
# farmers and %	7 (7.4%)	18 (19.1%)	40 (42.5%)	8 (8.5%)	14 (14.8%)	7 (7.4%)
Irrigation water cost	43	42	42	40	39	43
Herbicide cost	112	107	104	122	110	95
Pesticides cost	281	263	263	260	252	377
Fertilizer cost	842	615	587	569	689	711
Seed cost	224	171	211	162	179	197
Labor cost	356	330	324	323	324	319
Machinery services cost[17]	487	485	471	459	468	448
Paid interest on operating capital	440	353	295	260	325	243
Fix cost (tractor)	0	0	0	89	59	20
Total cost	2,785	2,367	2,298	2,284	2,445	2,453
Yield (unmilled, ton/ha)	9.0	8.5	7.7	7.1	8.0	7.0
Cost (USD per ton)	310	278	300	321	304	352
Sale price (USD/ton)	381	386	373	384	388	392
Average revenue per ha	3,223.7	3,217.1	2,847.2	2,711.7	3,080.3	2,713.2
Profit per ha	438.4	850.1	549.2	428.1	635.4	260.1

[16] The units are converted to USDThe original table used local currency, the Dominican dollars (1 USD = 34 RD$), and a local unit of mass, *fanega* (1 fanega = 100 kg of rough rice).

[17] Machinery service costs include land preparation, harvesting, and precision land leveling (Marte, 2012).

Table 4.4 Percentage of production costs

	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
Irrigation water cost	1.6%	1.8%	1.8%	1.7%	1.6%	1.8%
Herbicide cost	4.0%	4.5%	4.5%	5.3%	4.5%	3.9%
Pesticides cost	10.1%	11.1%	11.4%	11.4%	10.3%	15.4%
Fertilizer cost	30.2%	26.0%	25.6%	24.9%	28.2%	29.0%
Seed cost	8.1%	7.2%	9.2%	7.1%	7.3%	8.0%
Labor cost	12.8%	13.9%	14.1%	14.2%	13.2%	13.0%
Machinery services cost	17.5%	20.5%	20.5%	20.1%	19.1%	18.2%
Paid interest on operating capital	15.8%	14.9%	12.8%	11.4%	13.3%	9.9%
Fix cost (tractor)	0.0%	0.0%	0.0%	3.9%	2.4%	0.8%
% sum	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Based on past SRI literature from around the world, the following assumptions, as shown in table 4.4 were assumed in order to predict the financial impact of SRI method on production cost in the Dominican Republic. It was assumed that the cost for each factors listed in the table would be reduced under the SRI method, and the percentage of change in cost was assumed based on the actual cost saved in other parts of the world with SRI. Irrigation cost saved is generally in the range of 25%~50% [18] by SRI, thus the cost saved in the Dominican Republic was conservatively assumed to be 25%. Herbicide and pesticide cost saved is 50%[19] from the past SRI experience, thus the amount conserved was assumed to be 50%. Fertilizer cost is generally reduced in the range of 30~50%[20] from past SRI experience. It was assumed that fertilizer use would be curbed conservatively, about 35%, by SRI, due to its inherent dependency on chemical fertilizers and on the

18 e. g. Zhao et al., 2011; Adusumilli, 2011.
19 e. g. Sato, 2006
20 e. g. Styger et al., 2011; Sato et al., 2011

account of expected difficulty of changing the farmers' perception on the merit of using large amounts of fertilizers. Seed cost was assumed to be reduced by 80%., because rice is planted typically by 4~5 seedlings per hill while SRI plants 1 per hill. Assumptions were difficult to make for how SRI might change the machinery services cost as no past SRI literature discussed this factor, thus it was assumed to have no impact on change in cost. Similarly, cost on farmers from paid interest on operating capital was also expected to not change from adopting SRI method. Therefore, this factor was also assumed to have no impact on the change of costs.

Table 4.5 Assumed cost reduction for the calculations

% Increase in Yield	30%
Irrigation water cost	-25%
Herbicide cost	-50%
Pesticides cost	-50%
Fertilizer cost	-35%
Seed cost	-80%
Labor cost	-30%
Machinery services cost	0%
Paid interest on operating capital	0%

For the analysis, change in cost and percent decrease in cost from conventional methods were calculated for cases in which the rice production area allocated for SRI was 0%, 10%, 20%, 30%, 40%, 50%, and 100% of the current rice area cultivated conventionally. Calculation for 0% of SRI area means that the values are for conventional methods. Although the original data by Marte used local currency and unit for some parameters, the data was converted to US dollars and metric units.

In addition to cost analysis, profit was also calculated for two scenarios - first scenario in which yield does not increase despite employing SRI method of rice production, and a second, more optimistic scenario in which yield under SRI method increases. In both scenarios, it was assumed that cost of production is reduced, and that the same sale price of rice is applied to rice produced under both conventional and SRI methods. The profit that a farmer earns was calculated for a case in which the rice production area allocated for SRI was 0%, 10%, 20%, 30%, 40%, 50%, and 100% for both scenarios. For the second scenario in which yield under SRI increased compared to conventional method, the degree of increased yield was assumed to be 30%. This assumption is reasonable on the account of reported increase in yield across the world.

4.2.3. Environmental Impact

In principle, SRI advocates for less chemical inputs, because it places an emphasis on conditioning the soil to an optimal state for rice production. Table 4.6 shows the amount of N fertilizers applied in the Dominican rice production, and the recommended value calculated by IDIAF. The values here show that farmers are applying beyond what is recommended by the local research institution, as much as 50% more than recommended in some places. As seen in previous section, fertilizers are the most costly factor in rice production; there is a great opportunity to cut down both the cost of production and the environmental load through adoption of SRI.

Table 4.6 Amount of N fertilizers used in the Dominican rice production

Region	Northeast	Northwest	Southeast
Producers (kg/ha)	147	162	163
Recommended (kg/ha)	80-120	120-145	120-140
% beyond recommendation	22-49	11-35	16-37

While SRI is not necessarily an organic agriculture and therefore the use of organic fertilizers is not a must, it is certainly a desirable strategy if and when it is possible to do so. However, hearing survey with the IICA staff revealed that, in the Dominican SRI, the use of organic fertilizers has not been adopted, and it is likely to remain that way. Two reasons explain the lack of support for the use of organic fertilizers. First, many farmers in the Dominican Republic cultivate an area too large for realistic application of organic fertilizers. Larger farmers may have access to farm animals, but the amount of organic materials produced by such animals are not enough, and therefore insufficient for effective application in rice farming. Therefore, farmers are better off continuing using chemical fertilizers, rather than expend time and energy into producing and applying organic fertilizers. Second reason is that, while there are poor rice farmers in the country who cultivate rain-fed rice, they lack access to farm animals, the producers of organic materials, in the first place.

Based on the author’s personal observation, it does seem possible to produce enough organic fertilizer to substitute for chemical fertilizers, at least for small farmers. Even if they do not have access to farm animals whose manure would be a valuable resource, it seems feasible to produce organic fertilizers using crop residues and natural flora that flourishes in the countryside. Nonetheless, IICA is not willing to encourage farmers to switch to organic fertilizers. As a result, the Dominican SRI may have a limited effect on mitigation of environmental load from rice production.

4.3. Current Obstacles in the Development of the "Dominican SRI"

4.3.1. Labor Force

Visits to the field revealed that, while Haitian[21] laborers do their tasks as instructed by their Dominican employers, they are also not fond of the SRI method, particularly the seeding work. Conventional seeding practice in the Dominican Republic is such that direct seeding and transplanting are done in a crude manner. For transplanting, recommended practice is to transplant 4 or 5 seedlings per hill at lesser spacing, but Haitians often transplant with more seedlings per hill, and as high as 20 seedlings per hill, with disorganized and rough spacing. On the other hand, SRI transplanting requires 1 seedling per hill at 30 x 30 cm interval. This difference in required precision makes SRI method of transplanting a more time-consuming work for the laborers. However, this may be because the laborers are not used to the SRI method.

Even if the Haitian laborers took a special liking to the SRI method of cultivation, there are limits to the area that can be covered practically by manual labor. This may be due to the number of available laborers at the time of work, or the amount of money that the Dominican farmer is either capable of, or willing to, allocate to hire the sufficient number of laborers. SRI method of cultivation advocates for less use of agrochemicals, and intermittent irrigation, meaning that farmers must pay more attention to their field for weeding and other activities to care for their crop.

[21] In Dominican Republic, Haitians could refer to Haitians who migrate from Haiti, as well as those born in the Dominican Republic but under the Haitian parents. It may also refer to a mix of Dominican and Haitian.

Figure 4.2 Haitian laborer (specialized in transplanting)

4.3.2. Difficulty of Mechanization of SRI

Family-owned rice farms are found to be larger in general compared to other parts of the world. Management of larger plots is possible in the country by hiring the Haitian laborers. Tractors and land leveling technology is available in the country, but other tasks depend largely on manual labor. However, in order to efficiently operate a large plot of land, further mechanization is necessary. According to Juan Arthur of IICA, three types of machines are in particular need: transplanter, weeder, and harvester.

Mechanization of rice production process is not a problem unique to SRI. However, because SRI method plants at a wider spacing, transplanter need to either be compatible with both SRI method and the conventional method, or an entirely separate machine is needed for SRI method.

Chapter 5 Discussion

5.1. Effectiveness of SRI Practice in Saving Production Cost

Table 5.1 and table 5.2 show the cost of production under various mixtures of SRI areas and conventional rice production areas, and the percent decrease in production cost from conventional production, respectively.

Table 5.1 Estimated production cost by SRI and conventional methods

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
0%	$2,785	$2,367	$2,298	$2,284	$2,445	$2,453
10%	$2,706	$2,302	$2,231	$2,221	$2,378	$2,378
20%	$2,628	$2,238	$2,165	$2,158	$2,311	$2,303
30%	$2,549	$2,173	$2,098	$2,096	$2,243	$2,228
40%	$2,470	$2,108	$2,032	$2,033	$2,176	$2,154
50%	$2,391	$2,044	$1,965	$1,970	$2,109	$2,079
100%	$1,997	$1,720	$1,633	$1,657	$1,773	$1,704

Table 5.2 Percentage of production cost saved compared to conventional method

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
10%	2.8%	2.7%	2.9%	2.7%	2.7%	3.1%
20%	5.7%	5.5%	5.8%	5.5%	5.5%	6.1%
30%	8.5%	8.2%	8.7%	8.2%	8.2%	9.2%
40%	11.3%	10.9%	11.6%	11.0%	11.0%	12.2%
50%	14.2%	13.7%	14.5%	13.7%	13.7%	15.3%
100%	28.3%	27.3%	29.0%	27.4%	27.5%	30.5%

Table 5.3 and table 5.4 show the result of the profit calculations and percentage of profit increase for scenario 1, respectively.

Table 5.3 Profit from SRI and conventional methods under no yield condition

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
0%	$438.4	$850	$549	$428	$635	$260
10%	$517	$915	$616	$491	$703	$335
20%	$596	$979	$680	$553	$770	$410
30%	$675	$1,044	$749	$616	$837	$485
40%	$754	$1,109	$815	$679	$904	$560
50%	$833	$1,174	$882	$741	$971	$635
100%	$1,227	$1,497	$1,215	$1,055	$1,307	$1,009

Table 5.4 Percentage of profit increase with SRI and no yield condition

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
10%	18%	8%	12%	15%	11%	29%
20%	36%	15%	24%	29%	21%	58%
30%	54%	23%	36%	44%	32%	86%
40%	72%	30%	48%	59%	42%	115%
50%	90%	38%	61%	73%	53%	144%
100%	180%	76%	121%	146%	106%	288%

Table 5.5 and table 5.6 show the same results scenario 2.

Table 5.5 Estimated Profit from SRI and conventional methods with 30% yield increase

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
0%	$438	$850	$549	$428	$635	$260
10%	$614	$1,011	$701	$572	$795	$416
20%	$789	$1,173	$853	$716	$955	$573
30%	$965	$1,334	$1,005	$860	$1,114	$729
40%	$1,141	$1,495	$1,157	$1,004	$1,274	$885
50%	$1,316	$1,656	$1,309	$1,148	$1,433	$1,042
100%	$2,194	$2,462	$2,069	$1,868	$2,231	$1,823

Table 5.6 Percentage of profit increase with SRI and 30% yield increase

SRI Area/Total Area	Very Small (<1 ha)	Small (1-2 ha)	Medium (2-4 ha)	Large Medium (4-6 ha)	Large (6-20 ha)	Very Large (>20 ha)
10%	40%	19%	28%	34%	25%	60%
20%	80%	38%	55%	67%	50%	120%
30%	120%	57%	83%	101%	75%	180%
40%	160%	76%	111%	135%	100%	240%
50%	200%	95%	138%	168%	126%	300%
100%	400%	190%	277%	336%	251%	601%

SRI produces more with less input. Table 4.3 in Chapter 4 reveals that “fertilizers” are by far the greatest factor in production cost, while “pesticides” is also a significant portion of the production cost, accounting for 10~15% of all production cost at any scale of production. However, the cost of other resource inputs, i.e. “irrigation water”, “herbicide”, and “seeds”, each make up a small portion of production costs. Therefore, the degree of cost savings is the most dependent on how much fertilizer costs can be reduced.

However, cost savings from reduction of fertilizer cost cannot be expected too much for two reasons. First is that, in the Dominican case, substitution of chemical fertilizers by organic fertilizers are highly unlikely. Second reason is that, while research institutions may argue that farmers are using too much fertilizers and thus have a room for significant reduction in the amount applied, farmers themselves believe that they are making the best decisions in terms of the amount they apply to their fields, partly because they adhere to the claim by foreign fertilizer companies who recommend more amount be applied than the research institutions would.

Cost factors that are unlikely to be affected by SRI method, i.e. "machinery services cost" and "paid interest on operating capital", are also significant parts of the production costs. As a result, cost saved by SRI is not very high - even if all of the rice fields a farmer owns is cultivated under SRI method, at any given management scale, the reduced cost is expected to be less than 30%. Even if the farmer likes SRI, no farmer in the world produces his/her rice exclusively with SRI, and it may be the same in the Dominican Republic. Therefore, the cost saved compared to conventional practice is expected to be more or less at about 10% (table 5.2).

On the other hand, the increase in profit by incorporating SRI was calculated to be more significant than the cost saved. The percent increase in profit compared to conventional method was more than 10% in most cases, even if only 10% of the rice field a farmer cultivates is allocated for SRI, the yield did not increase, and the price of rice produced by SRI method is not discriminated from rice produced by conventional method. While the profit increase is generally in the range of 10~20% for managed area 20 ha or less when there is no increase in yield, percent increase of the profit doubles to the range of 20~40% increase if the yield was assumed to increase 30% under SRI method.

The most striking observation of all is the profit increase for farmers who cultivate a very large area (>20ha). Even without increase in yield, the profit has increased by 30% by cultivating only 10% of land by SRI. If the same 10% is cultivated with SRI for 30% increase in yield, the increase in profit compared to conventional becomes 60%.

However, the profit calculations also reveal that SRI for very large farms may be inefficient compared to smaller production scale. For example, cultivating 2 ha of rice field with SRI in a very large farm (assume 20 ha in total size) with 30% yield increase for SRI means that the ratio of SRI area to the total area is 10%, and the increase in profit is 60% However, cultivating the same 2 ha in a medium (2~4 ha) or a large-medium (4~6 ha) farm where the percentage of SRI area is 50~100% and 33%~50%, respectively, means that the expected profit increase is in the range of 138~277% and 100%~168%, respectively. This is a great difference in profit, suggesting that the scale of rice production and the degree of profit from SRI is not in a linear relationship. Ultimately, the calculations also suggest that while SRI can be applied at any given scale of rice production, it may not be scale-neutral[22] in terms of the benefit it may bring to the farmers.

Calculations are entirely theoretical, but they suggest that SRI in the Dominican Republic is a highly profitable activity once it becomes mechanized and practical. For larger production area, the calculation of costs and profits must be considered carefully. While large-scale production is more efficient, leveling the land becomes more difficult with larger paddy fields, and practical only with laser leveling, though this technology is available and is commonly used with large-scale producers in the Dominican Republic. Precision in leveling process is crucial, because even distribution of water and drainage is more difficult in larger paddy fields. SRI places great emphasis on draining the water to aerate the soil, but difficulty in leveling means that drainage and aeration of soil becomes uneven, which in turn makes the growth of the rice plant uneven as well, resulting in uneven yield.

In summary, SRI would have some impact on the cost savings of rice production. However, profitability will increase significantly, even if the yield did not change

[22] Sharif (2011) sought to adopt SRI for farmers of larger scale in Punjab, and has argued that SRI is scale-neutral on the grounds that its principles are biologically based.

under the SRI method. If the yield increases as it is expected with SRI, and if SRI rice can be sold with added-value, then the profitability of SRI will be further enhanced. Finally, the calculations showed that the SRI in larger scale may be just as profitable as it is in a small-scale, and especially so in a very large scale of management.

5.2. Applicability of SRI in Dominican Rice Sector

Table 5.7 organizes the general characteristics of rice production between developing countries, the Dominican Republic, and the developed countries (i.e. Japan, United States). The Dominican Republic is a developing country, yet its rice production management style has more similarities with the developed countries than the developing countries. However, while scarce supply of labor is supplemented by machines in the developed countries, visits to the Dominican Republic revealed that, in the country, the use of manual labor by Haitians are common and widely accepted practice. Dominican Republic and Haiti has had a historically complex relationship, and because of the wide gap in progress in national development between the two countries (see Appendix A and B for the difference), Haitians are often viewed as inferior to the Dominicans and treated as such within the Dominican Republic.

Table 5.7 Generalized characteristics of rice production

	Developing Countries	Dominican Republic	Developed Countries
Resource input	Low	High	High
Domestic labor resource	Abundant	Scarce	Scarce
Scale	Smaller	Larger	Larger
Yield	Low	Low	High

The author has been told (by the Dominicans) that Dominicans and Haitians enjoy a positive relationship within the sector. This claim is likely to be true, since the two groups are interlocked in a complex, mutually dependent relationship. The Dominicans are the powerful ones who have access to land and other resources, and make all the managerial decisions in rice production process, and exploit the laborers. While they are clearly politically weaker and economically poorer, Haitians have nonetheless adapted to this adverse social framework by specializing in certain tasks within the rice production process, making themselves more distinguishable from one another and economically more valuable. As a result, the Dominican farmers are not only completely dependent on the Haitians for carrying out the actual work required to produce rice, but also comfortable with the relationship. If the Dominicans are the heart and the brain of the rice sector, then the Haitians are the hands and feet that executes all the work.

Under such an uneven relationship, economic impact by SRI, or agronomic or technical innovations in general, affects the Dominican farmers and Haitian laborers unevenly also. Any increase in profit from SRI is the decision makers' to keep. On the other hand, although SRI also affects the work that Haitian laborers do, they do not have or gain access to the increase in profit. Furthermore, if and when the mechanization of SRI is successfully developed and implemented, it would also take away the work that Haitians have traditionally engaged in altogether. Essentially, economic inequality between the Dominican farmers and Haitian laborers are widened.

Over the years, dissemination efforts of SRI have targeted small-scale farmers who cultivate relatively small area of rice field. This has been due to both the purpose of SRI and its inherent limitation. SRI was developed to improve the livelihood of poor rice farmers with poor economic returns from rice production, and it has been the unchanging objective that development institutions have adhered to all along. At the same time, the labor-intensive nature of SRI meant that

SRI was difficult to apply to larger scale of rice production management, thus inevitably limiting the impact of SRI to small-scale farmers. Such a small-scale farmers who have adopted SRI have typically been responsible for both decision making in rice production (i.e. "when" and "how" of transplanting, weeding, irrigating, etc.) and the actual work that must be done under the decisions made[23]. On the other hand, the management structure in the Dominican case is significantly different, where the managers and the actual laborers are separate in the work relationship. Whereas the left side of the figure has access to the benefits of SRI as a unit, the right side, i.e. the Dominican case, the manager and laborers are a separate unit.

Separation of the management unit and the labor unit in itself is far from uncommon. In fact, in one instance, farmers who were targeted for SRI dissemination in Kenya had a same management structure, where the farmers hired laborers to do the work. The potential for a similar widening of economic inequality was observed here, in which the laborers, who does the weeding work, protested the introduction of mechanical weeder for fear of losing their jobs. However, the Dominican case has one more twist to the problem of inequality than the Kenyan case. While the farmers and laborers were both of Kenyan nationality and the mechanical weeder was introduced by foreigners, the farmers and laborers are of different nationality, and a potentially conflicting difference at that.

This difference in nationality is a complex issue in terms of rural development. The Dominican SRI is an initiative driven by the Dominicans, and for the Dominicans. Therefore, from a Dominican perspective, it is not a problem if the economic inequality widens as a result of adopting SRI, so long as the Dominicans are the major benefactor. As long as Dominican farmers are benefitting, the

[23] Of course, in strict terms, the decision maker who pick up SRI method and the actual laborer may be different after all - for example, a male farmer might decide to try an SRI, but it may be his wife that does the transplanting - but they are on the same side as they are typically a family.

Dominican rural development is arguably being advanced. However, from a more neutral perspective, rural development overall is not being achieved by SRI, due to the plurality of the parties affected by SRI. While there have been clear cases of a positive impact of SRI on rural development elsewhere, it is unfortunate that the Dominican case may not necessarily be a successful case of advancement in rural development via SRI. The Dominican case also implies that, for neutral development institutions, SRI may not be the right answer for rural development, and careful assessment of the manager and the laborer in production process should be conducted.

5.3. Significance of the Dominican SRI in Context of Latin America and Beyond

Dissemination of SRI in Latin American countries has been significantly slower and subdued compared to Asia and Africa. However, despite being one of the latest to initiate experiments with SRI, the Dominican Republic has been ambitious and swift. The difference is that, while any rice producing countries have a latent incentive to increase rice production the Dominican Republic now has an additional, overt incentive to protect the farmers from the threat from FTA impact. This urgent need to take action has been the sufficient incentive in the Dominican case for the sector to seek innovation, whereas the latent incentives failed.

This urgency may foster an innovation in the SRI. It is too early to tell the outcome, but if successful, the Dominican Republic may be the first country to successfully integrate SRI into mechanized rice production and implement the method at a larger scale.

In Latin America, Cuba has had a similar trajectory in which its SRI experience was driven by a sense of urgency, though much different in details. Due to unsustainable and insufficient agricultural practices and economic crisis in the 1990s triggered by the dissolution of the Soviet Union and a tightened embargo and increased political pressure by the United States, Cuba has suffered a severe food shortage and in great need of increasing its domestic food production. Today, Cuba continues to be greatly dependent on food imports, and in the case of rice, two-thirds of domestically consumed rice in 2008 has been an import (Uphoff, 2008). This urgent need to increase domestic rice production in Cuba served as an incentive for a quick dissemination of SRI in Cuba at a trial stage. Furthermore, over the course of experimentation and dissemination of SRI, this urgent need bred innovation in applying sprinkler irrigation, an attempt that is unique to Cuba, as well as an adaptation of SRI to sugar production. However, Cuban experience with SRI has arguably been a failure thus far.

The Cuban and Dominican cases share similarities in that both are highly motivated by an economic crisis of a national scale, and both attempt to reconcile somewhat archaic SRI with modern technologies in pursuit of more efficient rice production. However, the two are also quite different stories from each other, and have different degree of significance for technical and political reasons.

First, while Cuban adaptation of SRI with sprinkler irrigation is both interesting and may interest others beyond Cuba, it is not expected to be of great importance, because sprinkler irrigation in rice production is rare, if used at all. Likewise, the countries which produce sugar, a cash crop, are much more limited than those that produce rice, a nutritionally and culturally essential part of diet in many parts of the world. On the other hand, mechanization of rice production is much more common, and is an ideal practice in rice production. Therefore, mechanization of SRI is a much more relevant innovation in rice production than what the Cuban innovations offer.

The political reason is that Cuba is politically isolated, while the Dominican Republic is well-connected and integrated to the community of Latin American states. For Cuba, this is unfortunate - while it has been the first and by far the earliest country in the Americas to work with SRI and has shown great enthusiasm in disseminating SRI within and beyond Cuba, it has nonetheless failed to foster great interest in SRI in Latin America. Meanwhile, the Dominican Republic is “the weathervane of events taking place in Latin America” (Gragson and Payton, 1997), meaning that the Latin America are eagerly paying attention to events taking place in the Dominican Republic. Moreover, more countries are now involved in SRI, and are likely interested in further innovations and advancements.

Chapter 6 Conclusions

6.1. Findings of This Study

This study investigated the impact of SRI on rural development through literature review and the survey of the SRI experience thus far in the Dominican Republic. The impact was investigated by two approaches. Because increasing market competitiveness was the direct incentive for introducing SRI into the country, changes in costs and profits of rice farmers who adopt SRI method of rice production was calculated. It revealed that adopting SRI at all scale of rice production is likely to not have a significant reduction of costs, but could significantly increase the profit. Although SRI has been spreading across the world mostly to small-scale farmers, the results of this study indicated that a larger-scale SRI may also produce significant economic returns to the farmer, but that increase in size and profitability have a negative relationship. Most importantly, cost analysis also indicated that it has some effect in making rice farmers more competitive against emerging threat from foreign rice, and therefore make the rice farming economically more sustainable, though the impact of SRI alone is insufficient to fully adapt to the changing market environment.

Another approach to investigate the impact of SRI on rural development was taken by highlighting the difference between the managerial structures of Dominican SRI farmers with the SRI farmers elsewhere. By doing so, it revealed that the impact of SRI on rural development may not be so straightforward, in which it could benefit only a portion of a rural population while widening an income inequality among different players. Although aiding such disparity is unintended, this has to be expected given the pre-existing power relations between the Dominicans and the Haitians From a more neutral perspective, SRI is not the solution for the rural development of the Dominican Republic..

6.2. Challenges for the Future

Because the SRI in the Dominican Republic has only begun, some time needs to pass before the impact of SRI can be assessed truthfully. Actual calculation of costs, profits, and economic efficiency should be done to see the extent of the economic impact of SRI. The problem of FTA agreement and its impact on agricultural workers are not unique to the Dominican Republic, and may affect the farmers in other parts of the world. Thoroughly measuring the impact of SRI on economics of rice production would benefit farmers and researchers in understanding the merits and limits of SRI from economic perspective.

Meanwhile, another study should be conducted to assess how SRI impacts the laborers. SRI literature which deals with the human factors have so far focused on the impact of SRI on farmers as managers, rather than farmers as laborers. Therefore, studying the impact of SRI on laborers - their degree of acceptance of the practice, and if accepted, why, and what changes within the laborers - would be beneficial in understanding how SRI may be disseminated to areas in which managers and laborers are separate entities.

Appendix A – Human Development Index of SRI-Tested Countries

All	HDI	Ranking
Japan	0.901	12
South Korea	0.897	15
Taiwan	(0.882)	(22)
Cuba	0.776	51
Panama	0.768	58
Malaysia	0.761	61
Costa Rica	0.744	69
Peru	0.725	81
Ecuador	0.72	84
Brazil	0.718	85
Colombia	0.71	88
Iran	0.707	89
Sri Lanka	0.691	97
Dominican Rep.	**0.689**	**98**
China	0.687	101
Thailand	0.682	103
Philippines	0.644	112
Egypt	0.644	113
Indonesia	0.617	124
Vietnam	0.593	128
Iraq	0.573	132
India	0.547	134
Ghana	0.541	135
Laos	0.524	138
Cambodia	0.523	139
Bhutan	0.522	141
Kenya	0.509	143

All	HDI	Ranking
Pakistan	0.504	145
Bangladesh	0.5	146
Timor Leste	0.495	147
Myanmar	0.483	149
Madagascar	0.48	151
Tanzania	0.466	152
Senegal	0.459	155
Nigeria	0.459	156
Nepal	0.458	157
Haiti	0.454	158
Togo	0.435	162
Zambia	0.43	164
Rwanda	0.429	166
Benin	0.427	167
The Gambia	0.42	168
Afghanistan	0.398	172
Mali	0.359	175
Guinea	0.344	178
Sierra Leone	0.336	180
Burkina Faso	0.331	181
Mozambique	0.322	184
Burundi	0.316	185
Niger	0.295	186
North Korea	N/A	

Appendix B – Gross Domestic Product (Purchase-Power Parity per Capita) of SRI-Experienced Countries[24]

All	GDP	Ranking
Japan	34,314	26
South Korea	30,286	31
Malaysia	16,051	56
Panama	15,589	58
Costa Rica	12,157	72
Brazil	11,640	74
Iran	11,508	76
Peru	10,234	81
Colombia	10,033	83
Dominican Rep.	**9,796**	**84**
Ecuador	8,669	90
Thailand	8,646	92
China	8,400	93
Egypt	6,281	98
Bhutan	5,846	102
Sri Lanka	5,582	104
Indonesia	4,636	113
Philippines	4,119	117
Iraq	3,864	120
India	3,627	122
Vietnam	3,412	124
Laos	2,790	129
Pakistan	2,745	130
Nigeria	2,533	133
Cambodia	2,358	136
Senegal	1,967	142

All	GDP	Ranking
Ghana	1,871	143
The Gambia	1,809	144
Bangladesh	1,777	146
Kenya	1,710	147
Zambia	1,621	149
Benin	1,617	150
Timor Leste	1,578	151
Tanzania	1,512	153
Burkina Faso	1,301	155
Rwanda	1,282	156
Nepal	1,252	157
Haiti	1,171	159
Afghanistan	1,139	160
Guinea	1,124	161
Mali	1,091	164
Togo	1,049	165
Mozambique	975	166
Madagascar	966	167
Sierra Leone	871	169
Niger	727	171
Burundi	604	172
Cuba	N/A	
Myanmar	N/A	
Taiwan	N/A	
North Korea	N/A	

[24] GDP based on calculations for year 2011 by World Bank (World databank, 2012).

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