Farmer Centered Research on Improved Rice Cropping Systems in the Peanut Basin of Senegal:

Peace Corps System of Rice Intensification Extension Campaign

A Project Paper

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by

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ABSTRACT

This study assesses the potential of locally adapted methods of the System of Rice Intensification (SRI) to raise yields in 4 target villages in Kaffrine, Senegal. Imported rice purchases represent a third of household monetary expenditures, spending which farmers desire to reduced or eliminate. Subsistence production of the staple grain was recently readopted and local knowledge of rice growing techniques is limited. This project shows that a combination of local practices and best management practices (BMPs) inspired by SRI can raise yields to above household consumption needs without increasing labor requirements. This was determined through three phases; (I) a survey of local rice growing practices, (II) a training series for farmers in improved cropping methods and demonstration creation and (III) farmer centered field experimentation comparing local practices to three combinations of SRI inspired BMPs. The most successful combination of practices for both yield and labor savings in the area were in-line direct seeding using local animal traction machinery (achieving 35cm between-row spacing) and hand thinning the result at 8 days to 25cm spacing with one plant per hill. This work has given farmers in the 4 target villages the tools to sustainably increasing their yields in order to reduce dependence on imported rice. The successful adaptations also have the potential to progress the livelihoods of rice growers living in similar ecological environments throughout West Africa.

BIOGRAPHICAL SKETCH

Lorraine Perricone – Dazzo studied Philosophy and Anthropology at the State University of New York at New Paltz. This was followed by 1 year working as an AmeriCorps VISTA member in New York City where she served as a capacity builder at a multi-service community center. She then completed coursework for the Master of Professional Studies degree in International Agriculture and Rural Development at Cornell University as a Master's International student through the joint program with the United States Peace Corps. Her Peace Corps service commenced in August 2011 in Senegal West, Africa where she served as a Sustainable Agriculture sector volunteer for 2 years. She is interested in holistic and sustainable agricultural development work which focuses on soil conservation and community centered initiatives.

For the world's greatest Father/Daughter team without whom none of this would have been possible; Senne Mbaye and her father Babocar. Jeregeenjef.

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TABLE OF CONTENTS

FIGURES

TABLES

ABBREVIATIONS

ANCAR	National Agency for Agricultural and Rural Council
APCD	Assistant Peace Corps Director
CA	Conservation Agriculture
FAO	Food and Agriculture Organization of the United Nations
FTF	Feed the Future
GOANA	Great Offensive for Food and Abundance
IPM	Integrated Pest Management
ISRA	Senegalese Institute for Agricultural Research
JICA	Japan International Cooperation Agency
PCV	Peace Corps Volunteer
PNAR	National Program for Rice Self Sufficiency
SAED	Ministry for the Development of the Land of the Senegal River Delta
SDNR	Strategy for the Development of Rice Cultivation
SRI	System of Rice Intensification
USAID	United States Agency for International Development
USG	United States Government
WAFSP	West Africa Food Security Partnership
WARDA	Africa Rice Center

CHAPTER 1

INTRODUCTION

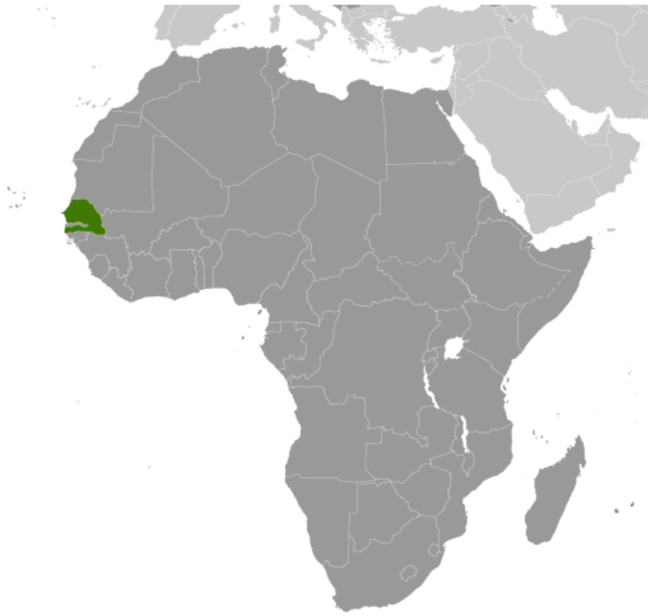

Figure 1: Senegal Location in Africa
Source: CIA World Factbook 2014

1.1 General Background

The West African nation of Senegal achieved its independence from the colonial rule of France in 1960. Since then it has maintained a stable and peaceful democracy despite civil unrest in neighboring nations, dynamism of cultural groups, and political corruption (Central Intelligence Agency 2014). The population is 94% Muslim, 5% Christian and 1% practitioners of indigenous beliefs. Countrywide 77.5% of the population works in the agricultural sector, the majority operating in small scale subsistence ventures (Central Intelligence Agency 2014). The crops most commonly grown throughout the country are peanuts, corn, millet, sorghum and rice. The rainfall amounts range from 250mm-500mm in the arid Sahelian zone in the north of the country to 900mm-1100mm or more in the southern zone of the country (Cisse and Hall 2002). This range of rainfall results in regionally differing preferences on crop selection and production methods. Rice is consumed in a majority of households daily even in those regions where it is not grown.

1.1.1 The Rice Economy of Senegal

Since independence food production in Senegal has doubled but the population has risen so dramatically the amount of food produced per capita has dropped by 50% (Bruntrup et al. 2006). Rice has quickly replaced millet and other grains as the favored staple to feed the proliferate population in both urban and rural households. Rice is much faster to prepare than millet or sorghum and low quality broken rice is relatively inexpensive. Per capita GDP has been rising steadily since the 1960's and with that the amount of imported Asian rice purchased has risen as well (Demont and Rizzotto 2012). Up to 25% of expenditures of rural households go to the purchase of imported rice. Many now prefer the broken grain to intact grain and will pound unbroken whole grain rice in mortar and pestle. Imported broken rice costs 10-20% more in markets then locally produced rice, which reduces the amount of domestic product sold (Bruntrup et al. 2006). This fact, along with the intensity of labor required, discourages farmers from engaging in rice production. This has resulted in Senegal being the second highest importer of rice by gross mass in Africa, with only the much larger nation of Nigeria ahead of it. In recent years Senegal has imported between 600,000 and 900,000 tons of rice which, combined with local production of around 400,000 tons, just meets domestic demand (Food and Agriculture Organization 2013).

As part of former Senegalese President Abdoulaye Wade's initiative, The Great Agricultural Offensive for Food and Abundance (GOANA), the government of Senegal pledged to increase the tonnage of locally produced rice to meet domestic demand by 2015. Other programs which aimed to improve rice production to meet local demand were the National Program for Rice Self-Sufficiency (PNAR), and the National Strategy for the Development of Rice Cultivation (SNDR) (Wolfe et al. 2009). This will not be achieved by 2015, but in partnership with the Japan International Cooperation Agency (JICA) the Senegalese Government has revamped their pledge to achieve the goal by 2018 (Coalition for African Rice Development). The strategy employed by the Senegalese Ministry of Agriculture to meet local demand for rice was primarily an irrigation infrastructure initiative in the Senegal River Valley (SRV). This 25,000-35,000 hectare area runs along the Northern border of the country between Senegal and Mauritania (Poussin et al. 2003) (see Figure 2). The infrastructure provisions are coupled with subsidized seed and fertilizer. Until 1987 a branch of the Senegalese extension system was dedicated specifically to managing these irrigation systems and input provisions to farmers. Since their withdrawal irrigation schemes are still provided with monetary incentives but have become liberalized; managed and run by farmer cooperatives. The outcomes of these schemes have begun to rely heavily on private sector influence as they control commercial functions within the rice value chain of Senegal (Wolfe et al. 2009). Irrigation and other mechanical inputs had received 60% of funds dedicated to the agricultural sector since the 1980's, mainly to support commercial rice and tomato production. This shows how policy has been biased toward commercial ventures despite the reality that 90% of land farmed in Senegal is under small-scale rain-fed conditions. In order to increase rice production by almost one million tons to eliminate imports the Senegal River Valley rice farmers require even further costly material inputs as well as technical education (de Mey et al. 2012).

A study done in 2002 determined that one hectare of land in the Senegal River Valley has the potential to yield 9.5-11 tons of rice but on average actually yields only 4.5 tons. This gap is the result of several factors including unsuitable cropping techniques, pest, weed and climactic pressures and improper soil fertility management (Poussin et al. 2003). Along with the agronomic obstacles, agricultural economists point out that in order to achieve its goal GOANA must focus on strategies to streamline the rice value chain; find ways to get the produce from the farmer to the consumers. This would entail investment in processing and packaging schemes which appeal to the local market. Further, consumers need to be sensitized to the availability of rice produced locally and its desirability (Rizzotto and Demont 2010). Rice farmers need to use consumer desires to inform decisions on variety use and packaging while the consumer needs education on the value of buying local rice. Currently credit is offered by only one provider, improved seed often does not reach farmers in a timely manner; the value chain itself has substantial holes and inefficiencies that make commercialized rice farming a risky endeavor (Wolfe et al. 2009). Farther up on the rice value chain, the famers themselves need to be given better incentives (e.g. prices, subsidies) to produce and market their product commercially. Such changes would, on the outset, effect only large scale producers but would ideally cut costs for consumers and possibly trickle commerce down to smaller producers. A focus on improved cropping techniques is necessary to make large scale and long term production viable.

1.2 The Major Rice Cropping Systems of Senegal

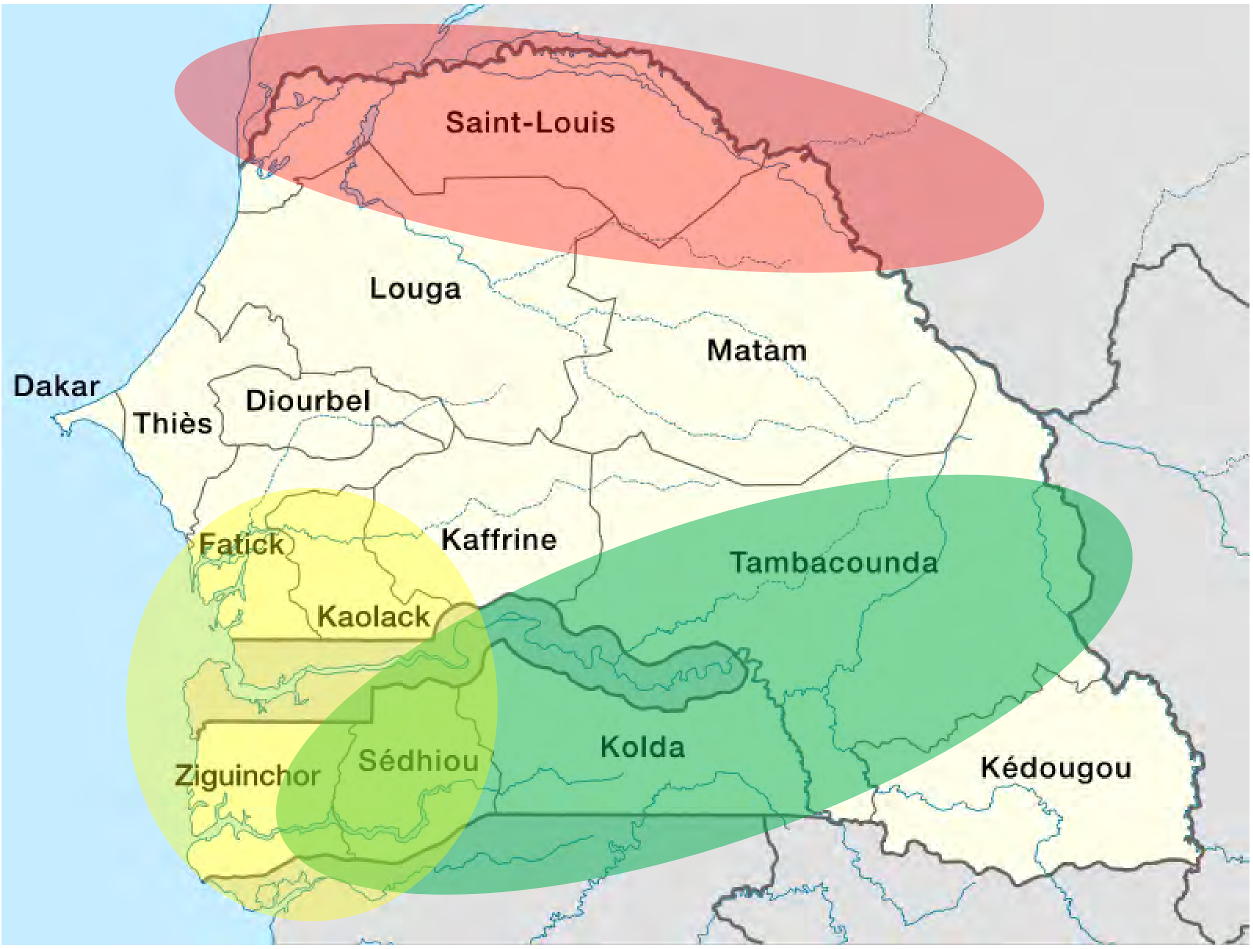

Figure 2: Map of the Regions of Senegal and 3 Major Rice Growing Regions
Red: The Senegal River Valley Yellow: The Delta Region Green: Ziguinchor, Kolda and Tambacounda
Source: Modified by Lorraine Perricone-Dazzo from
http://en.wikipedia.org/wiki/File:Regions_of_Senegal.svg#filelinks

There are two major rice growing regions in Senegal. The first is the Senegal River Valley in the St. Louis Region of the country and the second is made up of the southern Regions of Zigunchor, Kolda, and part of Tambacounda. A third, and less major, rice producing area is in the Delta Region of the Gambia River comprising the Regions of Fatick and Kaolack. Each of these areas has a predominant rice cropping system but farmers within each area take varying approaches to producing yields. Irrigated systems dominate The North while a mixture of hand and animal traction crop management methods are found in the rest of the country. Some farmers in the central and southern areas also implement unique mangrove rice systems. The sample villages of this study lie on the outer limits of the Kaolack region. Regional practices are influenced by both the systems of the Delta and the southern areas of Senegal but first, the northern practices will be discussed.

1.2.1 The Senegal River Valley

In Senegal 70% of rice produced domestically is grown in the irrigated systems of the Senegal River Valley. Farmers in this area also engage in recession agriculture which utilizes the soaked soils left behind by the river as it recedes in the dry season. The only source of water for agricultural use in this area of the country is the river and deep ground water. Rainfall is extremely low in this desert region and farmers struggle with upland field cropping systems. Those who have access to irrigation equipment use motorized pumps to transport water into bunded fields to manage lowland rice crops. Since access to water is always available these farmers can potentially produce two harvests in one year. Yields in this area range from 4-6 metric tons per hectare which has the potential to exceed household consumption among the farmers of these often shared field schemes. Policy has favored farming operations in this area in that they have received a lot of technical knowledge and physical inputs (see Section 1.1.1). This reality has made these operations relatively successful but they are not nearly reaching their full yield and marketing potential (Poussin et al. 2003).

Agronomic research has shown the constraints to achieving optimal yield in these schemes is often due to temperature and pest pressures and could be alleviated by improved timing of field interventions (Poussin et al. 2003). The decision making process for "irrigation schedules, land preparation, purchase of inputs (fertilizers, herbicides), harvesting and marketing of produce are all performed collectively at the scheme level" (Poussin et al. 2006). Financing for these operations comes in the form of credit which is paid back as a percentage of the yield, usually about one third of the total (Wolfe et al. 2009). This credit is taken on as collective loans, meaning that both the cropping system and finances of farmers are dependent on the decisions of the entire group. Recommendations provided by Africa Rice (previously the West Africa Rice Development Association or WARDA) to the rice extension education system SAED regarding chemical application timing are often not employed by farmers, most likely due to labor constraints (Poussin et al. 2003).

Labor inputs in these systems are generally mechanized by animal traction or motorized tools. Soil preparation, seeding, irrigation and weeding are done by locally bought or rented machinery. These systems are male led since it is highly mechanized and a cash crop is being produced, both marks of male agricultural domain. The fields are often pre-flooded to loosen soil and then arranged in bunds to retain water in a patchwork of rectangular segments, each level with the next. As the water fills one area the excess is let out via spillways or piping into the next segment, until all have filled. The fields are then flooded again for two days and the soil is worked by animal traction machines in preparation for seeding. These irrigated schemes are direct seeded or transplanted with approximately 30 days old rice seedlings, or some combination of the two establishment methods. Weeding is performed by animal traction plows with specialized attachments for weed removal. If a farmer can afford it, pest attack is combatted with pesticides purchased at the market. These chemicals are often misused in that they may not be appropriate to control the target pest or may be applied after the population threshold is too high, rendering them ineffective. In summation, the irrigated rice cropping schemes in the north of Senegal are somewhat lucrative and have been viewed by extension and aid programming as having the potential to reduce or eliminate international rice imports, but this goal is not yet close to being fulfilled.

1.2.2 Ziguinchor, Kolda and Tambacounda

Farmers in the regions of Ziguinchor, Kolda and Tambacounda utilize high rainfall and lowland flooding to produce rice in hydric and upland soils. The rice yields produced in the rain-fed areas, both in these regions of Southern Senegal and the Delta Region, generally do not reach the market but is kept for home consumption. An exception is when a percentage of the yield is given to repay debt or the cost of milling. This is the only situation where a surplus is created and rice produced in rain-fed schemes may reach local or wider markets. As previously mentioned most of the rice cropped in Senegal which reaches a commercial market is grown in the Senegal River Valley, not in these rain-fed systems (Wolfe et al. 2009). Rice producers in the Ziguinchor, Kolda, and Tambacounda areas do not have access to as much mechanization as those in the north and must rely on hand seeding, weeding, and harvesting (McClintock 2006).

Some animal traction machinery is available in areas close to cities and for those who can afford it. Due to adequate rainfall amounts, usually 1100 mm or more annually, successful rice systems can be established in deep or shallow lowland seasonal flooding patterns or even in upland situations. The ecological area is classified as dry Guinean Savannah which has a long dry season making two rice campaigns per year impossible (Sall 1998). Large variations in soil quality and type can be found throughout the rice growing areas of this region which results in farmers' utilizing various appropriate techniques and varieties. Differing socio-economic status' also contribute to farmers' taking divergent approaches to crop establishment. The resources and labor available to a household, along with perceived importance of the crop, will affect the crop management style taken by a farmer tending any given plot.

Farmers in these regions generally prepare their plots using hand hoes and may create bunds around large areas or many smaller rectangular plots. Seeds are often broadcast inside of, or along the bunds of these plots to take advantage of flooded conditions. While the rice plants grow along the tops of low bunds the rain water pools inside the square plots and acts as irrigation (Carney 2009). This ridge cropping can often be found in shared community cropping spaces. The majority of farmers choose to transplant seedlings they establish in field or home-garden based nurseries. This approach requires more labor than broadcasting but assures optimal spacing and generally higher yields (FAO Corporate Document Repository). The seed varieties used by these farmers are likely to be local, including West African *O. glabberima*, having been passed down and shared for generations. Farmers take into account the environmental conditions in their plots when choosing a variety, often utilizing regional knowledge of past successes. Research and extension efforts generally encounter farmers willing to try improved varieties. The local psychology is to trust the quality of introduced physical inputs like seed and chemical fertilizer. Without the pairing of particular crop management practices it has been found that these improved varieties do not perform as well as local varieties in poor conditions (Sall et al. 1998). This fact should direct future genetic seed research and education campaigns in participatory variety selection.

Approximately an equal percentage of the total rice harvested in Senegal comes from irrigated schemes and lowland rain fed systems even though 90% of the farms lie in the latter area. This is due to many barriers to intensification which could only be remediated by increased inputs, market support and education (FAO Corporate Document Repository). A main physical constraint to these rain fed systems is potential flooding and yield reduction or total loss due to lack of irrigation control. The converse issue is the possibility of erratic rain events, early end to the rainy season or drought which can put high pressure on the plants. Pest and weed management are difficult due to lack of mechanization and weed pressure often reduces yields. Farmers generally produce just enough, or less than their household needs, for the year. Culturally rice is viewed as a crop grown primarily by women in these regions although most villages will have a few men who keep rice plots. Most of the attitudes and practices regarding rice cropping in the south of the country outlined here are similar within and above the Gambia in The Delta Region of Senegal.

1.2.3 The Delta Region: The Fatick and Kaolack Regions

The departments of Fatick and Kaolack give home to many rice farmers who engage in the various rain fed lowland and upland systems described in the last section. There is often an increased presence of aid development and government support and a higher prevalence of animal traction machinery available to farmers in this region as compared to the south of the country. Due to this a focus on animal drawn machines for soil preparation and weed control is more common. There remains a mixture of establishment techniques including broadcasting, machine seeding and transplanting. Rice here is generally considered a women's crop and many cooperative women's farming groups create spaces where they produce the grain for subsistence purposes.

Rice had been farmed in this region, through The Gambia and into the southern part of Senegal as a women's crop traditionally for hundreds, if not thousands of years. The predominant cultural group in The Gambia River delta area, the Mandinka, are known for their rice production. In the past the harvest, for which she did most of the labor, with some help on specific tasks from males, was the property of the woman herself. As early as the 1400's when Portuguese explorers were travelling along the coastal and delta regions of West Africa, female rice farmers would broker trades of their rice with sailors who needed supplies. In the mid-18th century bountiful rice harvests of the delta caught the attention of French, and later British sailors who began a lucrative trade with these female farmers. Seeking to increase exports from the region, Britain later considered intensifying rice production to recreate the successful slave labor rice systems in the south of North America. In fact, the success of the New World rice plantations has been attributed to the transfer of rice growing knowledge from West African slaves into this region (Carney 2009).

Plans to exploit the West African rice market for exports were quickly abandoned as peanuts came to the forefront of lucrative colonial exports. While females were in charge of rice production, males traditionally dedicated their agrarian efforts to other staple grains like millet and sorghum. They shared field spaces with women in rotations between male staple grain crops and women's dry season vegetable gardening, lending a helping hand to each other in each. As the groundnut boom commenced, and rapidly grew, males started to dedicate their land and labor to this crop, often abandoning the arrangements of the past. Because of this the household requirement for staple grains was no longer being met by domestic production. Further pressure on consumption patterns in the area was created by the import of seasonal workers required to fuel the peanut industry. This created the economic climate in which rice imports first became necessary to West Africa. This process also increased pressure on the female farmers to intensify their rice production to meet dietary needs. It remained the responsibility of females to feed the family despite having lost land and labor to the peanut industry (Carney and Watts 1991).

Whereas before females may have been earning goods and money through rice trade, accruing wealth they could control, males were now in control of all money earned. Women are more likely to reinvest their monetary holdings into calories and services for the family, so an over-all reduction in quality of life was likely experienced. Since most up-land plots were acquisitioned by males to utilize in peanut production, females were relegated to farming exclusively in the lowland flooded zones. The idea that the lowland is a women's zone is held to this day in Mandinka cultures in the Delta Region and far beyond, including the four target villages of this study (Carney and Watts 1991).

Farmers also produce rice as part of complex land management systems which spread through the delta. These systems range from the Kaolack area down the coast of West Africa through Guinea Conakrie and Liberia. Tidal mangrove forests grow in brackish salt marshes which hug the coastline of West Africa. Farmers utilize natural flood plains that exist behind these forested zones to crop flooded rice, employing systems of dykes and dams to control salinity and irrigation. When most upland spaces in the Kaolack region became relegated to peanut production, female rice farmers began to further encroach on the mangrove forest zones to increase their available land area for rice production (Bos et al. 2006). This has contributed over time to the loss of biodiversity in the mangrove forests which is currently threatened with extinction (IRIN 2008).

1.3 Agriculture in the Region of Kaffrine

The test villages for this study all lie in the region of Kaffrine in Central Senegal where animal traction systems of peanut and millet dominate the landscape.

1.3.1 Major Crops

The major crops produced in the region are peanut, millet, corn and cowpea; millet and peanuts being the most prevalent. Secondary crops of sesame, Bambara Groundnut and Pigeon Pea are grown in field crop spaces. Gardens commonly contain tomato, squash, okra, bitter tomato, eggplant, hot peppers, lettuce and cabbage. Most households contain a mango or papaya tree but some farmers keep protected mixed orchard and garden spaces with higher volumes of mango and papaya, often with improved varieties. Other common fruit trees cultivated are guava, sweet sop, and citrus but are much less prevalent than mango or papaya. Throughout the year various 'bush-fruits' can be harvested from trees left standing in fields or small patches of protected forest found throughout the region some examples being baobab fruit and jujube. Most trees have been cleared away to develop agricultural spaces easy to manipulate with animal traction machinery. The area has been 55% deforested but farmers have left interspersed trees in agricultural landscapes they find to be useful (Monga Bay 2014). Some calories are derived from these sources but the main dietary staples are corn and millet porridge, imported rice and peanuts.

1.3.2 The Peanut

Peanuts are not indigenous to West Africa but were introduced by European explorers in the 16th century. The climate and landscape is well adapted to ground nut production and farmers had adopted the species by the early 1800's. Peanuts can be grown in dry-land areas and offer a buffer for the possible loss of other staple grains like millet. Exports of peanuts to Europe began in 1830 and quickly grew in order to meet the need for oils in newly industrialized systems. By reducing taxes on the import of unshelled peanuts France was able to take control of profits made through peanut oil production. This economic relationship between France and the peanut producing region of Senegal then turned into their political control. Colonial leadership was in the position to create policy that promoted the peanut industry including agricultural extension efforts, some form of which still exist today. The agricultural industry employs 70% of people in Senegal, of which the majority produces and sells peanuts (The World Bank 2014). The Kaolack, Kaffrine, Diourbel and Louga regions are often referred to as The Peanut Basin since production is centralized here. The railway system passes through these region's capitals where historically peanuts were brought to Dakar for export, and are still utilized today (Moitt 1989). Farmers are provided with peanut seed and are expected to sell it back to the government at around 190CFA per kilogram. Competition from markets in neighboring countries and other foreign interests, combined with unstable yields from year to year, make the benefits of this system unsure for both farmers and the Senegalese government.

Besides creating one of the area's first export economies and shifting land use practices it also affected the dietary patterns of rural populations in the Kaffrine region. Along with millet and rice, peanuts are eaten in most households on daily basis either whole or pulverized to powders or butter. The hay is used as rich animal feed and the shells are incorporated into soils to increase fertility. The rotation of the leguminous crop with heavy feeding cereals like millet and corn reduce pest pressures and ameliorates soils. Even with the integration of crop rotation larger environmental and land use factors assure erosion, deforestation and soil nutrient mining are still serious problems. The population of The Peanut Basin far exceeds the carrying capacity of the land which explains the trending pattern of food imports and human labor exports. Many households depend on remittances sent by family members working abroad or in large cities, some of whom return home in the rainy season to farm (Diatta and Mbow 1999).

1.3.3 Mechanization

The usage of animal powered agricultural equipment, which increased dramatically in the period following independence in 1960, has allowed relative intensification of production. These tools were originally manufactured by a French enterprise but local metal workers adapted methods of building and modifying the tools (Starkey 2000). They contributed to reduction of labor inputs in all field crops, not just the peanut for which it was originally designed. Farming households struggled to find enough labor to produce cash crops and subsistence harvests. Peanuts are farmed in the Kaffrine region on a large scale, but a higher percentage of agricultural space is still dedicated to millet to meet subsistence needs (FAO Corporate Document Respository). Forests have been cleared to allow for the straight lines the machines are designed to ridge and seed in. The purchase of these tools is readily available in large towns and the capital of the Kaffrine Region as they are made by local metal workers in markets. Most farming households can afford a plow, seeder and weeding attachments which are drawn by donkeys, horses or cows. Farmers have learned to maintain and adapt the usage of these tools to meet many of their needs.

These animal drawn implements also mark the division of agricultural labor along gender lines. The tools are used to gather crop residues to be burned, loosen soils, distribute seed, and remove weeds between rows and, in the case of peanuts, to dig the produce from the ground. The maintenance of the tools, care of the animals and execution of these tasks is the job of male members of the household. It is very rare to see a woman guiding an animal or machine in the fields. Women's responsibilities in field crop spaces include hand thinning millet or corn, hand weeding within rows, gathering and winnowing grains, beans and peanuts, and processing the harvests to be eaten or sold. This includes pounding and sifting grains, hand shelling peanuts and beans, and drying and cooking the produce. This is the general labor sharing arrangement the farmers involved in this study implemented in their rice fields. The machine seeding of rice in the experimentation phase of this study, when combined with other altered cropping principles, gave impressive results and thus was an important variable.

1.3.4 The Cultural Roots of Rice in Kaffrine

Senegal has 56 distinct people groups, the largest identifies as Wolof followed by Puular (Central Intelligence Agency 2014). The target villages involved in this study lie in the region of Kaffrine and are primarily Wolof with a small *Tukuleur*, or 'Northern Puular', minority. Their populations range from 300-800 people. Wolof speakers country-wide represent a multi-ethnic group who are increasingly self-identifying as culturally Wolof. The traditions of the 43.3% of people in Senegal who consider themselves Wolof are mixture of practices from various West African groups that have amalgamated over the past half century or more (Central Intelligence Agency 2014). This includes their agrarian behaviors and attitudes towards rice production which utilize Mandinka techniques, Malian varieties and Wolof machinery.

The rice cultivation practices found in Senegal and The Gambia area described in the previous sections are restricted to these countries or their political regions. The technology and practices implemented by farmers spread naturally along water ways, eco-systems and cultural interactions. Although the department of Kaffrine does not necessarily lie in the well-known rice producing areas of The Delta or Kolda, it is located between them and its southern-most limits are in proximity to The Gambia River. The Kaffrine region contains tributaries of The Gambia River and along them the country's rice traditions (See Figure3). Climactic changes over time, especially the great droughts of the 1970's and 80's reduced the size of the mangrove forests of the delta and aggravated issues of salinization (Bos et al. 20060). The effects are even starker further inland along the tributaries of the river. The Bao Bolong tributary cuts through the department of Kaffrine southwest down to The Gambia River. It meets the river only 40 kilometers east of where one of the river's largest tributaries the Bintang Bolong, meets it (Google Maps). According to farmers living in the area, the volume of water flowing through the *bolongs* has reduced in the past 50 years and become much saltier, limiting agricultural potential. Deforestation has increased erosion along the waterway causing reduced soil moisture retention and increasing percolation, lending to salinity issues.

Figure 3: Map of the target village test area in relation to the political regions of Kaffrine, Kaolack and Tambacounda. Also pictured is The Gambia River and Bao Bolong tributary. Source: Created on Google Maps by Lorraine Perricone – Dazzo

The farmers working the seasonal freshwater systems of the northern limits of the West African rice cultivating area traditionally did not control water flow for irrigation. Rather they utilized the natural flow of water to bring nutritious alluvium on to their soils (Carney 2009). Colonial agriculturalists mistook this lack of control for a primitive system, produced by an undeveloped society, when in fact it was part of sophisticated land-use practices. Farmers, as they still do today, allowed the seasonal water pattern to dry in order to utilize the changing environment for crop diversification, a combatant against famine. As the waters recede vegetables or a heavy-soil loving grain like sorghum can be planted. These systems would often utilize the graded depths of this natural waterway to stagger plantings of different varieties of rice, creating insurance against crop loss. Traditionally women living in these areas have extensive knowledge of the dozens of different indigenous varieties and their uses (Agyen-

Sampong 1988). In the target villages for this study, systems of staggered rice plantings and diversity of variety usage have been abandoned but not completely forgotten. Another reason for allowing the waterway to ebb and flow naturally is to create open spaces for grazing cattle in the dry season. Since the region is utilized by migratory herders, and sedentary populations generally own animals as well, grazing material is needed in the dry season. The droppings of these animals ideally become incorporated into the fields, managing soil fertility for the next rainy season. This is another food security measure as the milk and meat of these animals brings nutrition and calories in the dry season. Even more importantly, these are the animals which provide the plough traction in all Kaffrine region field crop spaces.

During the course of this study a development project was designing and planning a complex dam system to be installed in the waterway flowing through the 4 target villages and one village to the northeast, Diouly Mandakh. The project is funded by the Belgian Development Cooperation and executed by their field agents and Djamel Consulting International (Belgian Development Cooperation 2013). Their goal is to allow farmers to have two rice harvests, instead of one, per year by providing them with water control. This disrupts the system which was just described, but the success of the balance it strikes has already been compromised by harsh climate and overproduction. The dam may allow farmers to combat salinization and achieve the intensification pursuits with which they are already stressing the landscape. Future monitoring and evaluation of the project will be necessary to assess its environmental impact and food security potential. Although these lowland rain-fed systems are common throughout West Africa, Kaffrine represents the north eastern most limits of where they are found. This explains the marginalized and unsystematic approaches taken by rice farmers here. The vast majority of farmers in the Region of Kaffrine does not have access to the Bao Bolong waterway and thus focus their agrarian efforts on upland staple grains and peanut production.

CHAPTER 2

RESEARCH BACKGROUND

2.1 The System of Rice Intensification

As was noted earlier, a variety of forces have resulted in Senegal being ranked as one of the top rice importers in the world. The government and free industry have set goals to reduce or eliminate dependence on these imports. Working against them are severe constraints to agricultural production including environmental degradation, climactic shifts, policy limitations and out migration of the agrarian work force to large cities or abroad (Golan 1994). The start of the Green Revolution in agricultural development in the 1960's marked the beginning of systems of intensification which got more food from less land. It achieved this through specific inputs and improved management recommendations (Borlaug 2000). These methods are still utilized to produce ever increasing yields to feed the proliferate populations of the world. They have the ability to coax production levels from the earth that, in many cases, would otherwise be impossible; an often necessary measure to match production to consumption needs. Agricultural development practitioners have continued to research methods for getting more food from less land but with a refocus on ecological renewal (Uphoff 2012). The System of Rice Intensification is one such methodology, now in its third decade of conceptualization and research.

2.1.1 Background

The system has gained impressive traction over the past decade as a basis for rural educational and research efforts, drawing attention to the importance of rice as a staple crop worldwide. Many international agricultural initiatives have used the 'market bundle' of SRI principles and poor-farmer friendly image as a platform for education and rural livelihood improvement efforts including the International Fund for Agricultural Development (IFAD), Africare and Peace Corps (Binju et al. 2014).

Similarly to Green Revolution approaches, SRI is designed to achieve increased yields from altered management practices and often improved chemical and varietal inputs as well. The specific SRI management practices which are most commonly cited were pieced together by a French development worker and missionary, Fr. Henri de Laulanié, S.J, working with rural agrarian communities in Madagascar in the 1980's (Fisher 2014). He did this through observations of certain innovative farmers' methods, which he combined with methods he determined in field experimentation. In his years of testing he noted the positive synergistic effect of some altered crop management practices in these Malagasy rice fields; the transplanting of young seedlings (15 days old or less), placing only 1 seedling per hill, establishing the crop in wide and even spacing (25cmx25cm minimum), rotary weeding to incorporate organic matter and oxygen, and reduced water inputs to maintain aerobic soil conditions. Initially chemical fertilizer was used as part of the system since the perceived necessity of its use was the zeitgeist of agricultural intensification at the time. When Malagasy government subsidies of the input stopped he and his farmers discovered using compost was equally effective (Uphoff 2012). Nutrient-use efficiency and nutrient uptake in conventional and intensive (SRI) rice cultivation systems in Madagascar

These practices resulted in exceptional yields in the Malagasy ecosystem and within the management capabilities of the farmers (i.e.: compost and labor availability) (Barison 2003). SRI proponents claim that these successes as well as later ones were caused by certain synergistic effects. By altering watering schedules, and aerating soils during weeding, oxygen is delivered to rice roots which may improve rice root growth (Kar 1974). They claim the synergistic effects of the decreased root damage at transplantation, increased oxygen and wide spacing improves root development and increases yield. When applied to some traditional irrigated systems these new practices might decrease seed, water, and labor inputs. Increased spacing and lower transplant density means less seed is needed. Intermittent irrigation where water control is available uses less water than traditional continually flooded systems. Further, if they are available, the use of special tools like rotary weeders to mix weeds into the soil decreases labor in certain soil conditions. The purchase of improved variety of seed and fertilizer may not be necessary which saves on monetary expenditures, although these could be important for yield potential in some areas.

The field actions being employed to achieve these purported synergies are the same as the individual best management practices (BMPs) recommended by rice researchers for some ecological systems (IRRI 2007). The BMPs of any specific rice field must be determined through consideration of many factors including hydrology, labor, variety, soil type, equipment availability and variety. Optimization of these factors in each environment is all integral to achieving a good rice yield. Since the SRI group of management practices showed such great success in Madagascar it was given its own title as a package by proponents hoping to spread knowledge of this specific set of BMPs. In 1994 the Cornell Institute for International Food, Agriculture and Development partnered with Laulanié’s educational center in Madagascar to expand their operations. The partnership resulted in Cornell establishing its own SRI-Rice initiative which supports SRI researchers and farmers worldwide through several initiatives. One of their current initiatives in West Africa trains Peace Corps Volunteers and their partners in adapting and testing direct seeded and transplanted adaptations of the SRI methodology. The training prepares volunteers and farmer leaders to educate small scale rice producers in SRI principles and monitor pilot attempts. The farmer centered research conducted for this study in Senegal was informed by this training program which I attended in May 2013 (Jenkins 2013).

Although the management practices put forth by the system have proven to be successful in Madagascar and some other areas there is no guarantee of the success of these particular practices in new climates or cultures. Some rice researchers believe that SRI promoters' claim "that the system unlocks a genetic potential of rice that is otherwise unattainable" is not true They believe the same potential can be reached or exceeded by other BMPs, as they are in-fact similar to the SRI practices (McDonald et al 2006). It is not possible ecologically, economically or socio-culturally to implement all aspects of SRI in all places so trade-offs must be explored and tested. These alterations may be informed by or coincide with BMPs and the general capacities of the farmers and their land. It is difficult for field researchers to subject the system to rigorous agricultural research methods due to the many factors influencing its success; this work should be taken up by research scientists (Glover 2011). Further, rural rice farmers do not conduct a homogenous set of actions in their fields, even when they are cropping side-by-side. It was some of these small differences that inspired the exploration of SRI practices by Laulanié in the first place and what drives development workers and farmers to create adaptations in agricultural systems. This can and should be complimented by BMPs determined in laboratories and field trials.

The field research conducted for this study tested adapted rice cropping techniques which were inspired by the SRI principles. Without the popularity of the system which is fueled by its marketability, the group of farmers I worked with would likely have never received training in improved rice cropping. The training included information on agroecological principles that are important for any farmer to know like soil conditioning and composting. These farmers were also encouraged to engage in experimentation and gained experience in creating field demonstrations. The capacity building and empowerment effect on the test villages were real successes of this project. The farmers were given tools and knowledge with which to explore possibilities for improvement of their rice cropping activities. It opened up many channels of communication between individual farmers and villages, tapping into existing knowledge and capabilities to benefit the collective. It also introduced new ideas which were rooted in researched SRI and BMP principles. Farmers were not told that this was the only way to grow rice, but to explore and experiment with it as a possibility.

The ‘field-view’ of SRI promoters inspires their passion because they often see the improvements in both rice yields and farmers’ confidence. It is from this stand point that SRI proponents can cite the rapid and wide-spread adoption rates which they hold as evidence of the system’s benefits. If it is easier for a farmer to implement the SRI group of BMPs than others it may increase their yields without increasing other inputs. SRI is really a group of BMPs inspired by and designed to benefit small-holder farmers who are in need of not only improved methods but inspiration and education. The SRI movement, as it has for this research, often brings the elements of adult education and community organizing where they wouldn’t have been otherwise.

2.1.2 SRI in Senegal and The Gambia

Testing has been conducted in the Senegal River Valley by Timothy Krupnick and in The Gambia by Mustapha Ceesay et al. All of their experimentation was conducted under conditions with controlled irrigation. Their findings exhibit mixed results and their recommendations differ. Yield increases and economic benefits were noted in The Gambia as compared to national averages (Ceesay 2011). Ceesay promotes SRI as a way to raise yields and encourages testing of improved NERICA rice varieties within the SRI context. He makes the strong point that farmers increasingly need to take water conserving measures as the resource becomes scarcer. He views this as an integral benefit of SRI for West African farmers as alternate wetting and drying showed better yields than continuous flooding (Ceesay 2006). The testing done in the SRV by Krupnick compared SRI to BMPs and found no yield improvement from the former to the latter although there was water savings and better long term response to organic matter inputs in SRI (Krupnick 2012). Water savings were limited when weed pressure was put on SRI fields, a common impediment for African farmers. Even under weed pressures water savings ranged from 16%-48% in SRI plots and yields were generally equal to BMPs when soil amendments were the same (Krupnick 2012). He does encourage further research to understand the water saving mechanisms at play but does warn that higher yields should not be expected as compared to other BMPs. He adds that any farmer who wants to experiment with SRI should amend their soil with rice straw because he found its long term effect on yield was positive. Mineral fertilizer inputs were used in all of these experiments with poor soil quality cited as the reason.

Starting in 2008 the local extension program began SRI experimentation in the northern region of Matam. The total area farmed under the technique is now 80 hectares (Cisse et al 2012). Results from this experimentation have shown yield increases and resulted in farmer education initiatives in Matam and The Delta regions. The results were presented at a Regional Workshop on System of Rice Intensification (SRI) held in Ouagadougou, Burkina Faso, on July 26 and 27, 2012. Farmer centered education and testing was conducted by Carrie Miner in the southern Kolda region of Senegal in 2006. The work was done as part of her extension efforts as a Peace Corps Volunteer with 6 female participants. Her project showed positive attitudes towards the adaptation of the system they tried which included wider spacing and seedlings being transplanted at a younger age (McClintock 2006). The ease of hand weeding in the wider spacing was noted and is a benefit to female rice farmers in the Delta region as well.

2.2 Target Village History and Selection

The data collection activities for this study took place in 4 villages in the region of Kaffrine; Mouille, Taiba, Ndiaycounda and Keur Demba. These activities occurred in 3 phases; I survey, II training and III field research. As a Peace Corps volunteer I lived and worked in the neighboring village of Diouly as a field crop extension agent for approximately 1 year before starting the first phase. The next sections, 2.2.1 and 2.2.3, are a summary of my early impressions of the region which relate to this study. They elucidate the conditions which led to the objectives and methods described in Chapters 3 and 4 including an SRI demonstration at the Katakel Master Farm site. These conditions were in short, an agrarian community where area farmers were rapidly adopting small scale rice production in the waters of the Bao Bolong tributary in an effort to decrease household spending.

Figure 4: Target Villages and surrounding locations involved in project execution
Source: Created on Google Maps by Lorraine Perricone - Dazzo

2.2.1 Early Assessment

A tributary of the waters of the Bao Bolong Wetlands, primarily located to the South in the neighboring country of Gambia, travels seasonally through the village of Diouly in which I lived from November 11, 2011-November 10, 2013. About 5 farmers in Diouly, a village of 200 people, utilize the clayey soil along this flooding pattern to cultivate small plots of local or improved rice varieties. The water is dammed as it passes between Diouly and its neighboring village to the West; pooled into a deep reservoir in order to attract migratory birds. The wall holding the water was built by the management of a hunting resort located in the village of Katakel approximately 12k to the East. Surrounding the dam is old growth forest complimented by plantings of *Acacia sayel* and *Acacia nilotica* which also attract migratory birds for hunting. The wetland area suitable for farming is small and very few farmers have access to this prime field cropping space. Most of the wetland areas which are not taken up by the dam and forest are used as shared community garden spaces. These spaces are used to grow tomatoes and a medicinal plant called *leydour*. These spaces are relegated to female gardeners and the loosely organized village-wide women's collective. These lowland spaces are historically relegated to female farmers as peanut cash cropping is reserved for upland fields (Corcoran 2007).

Moving east along the Bao Bolon, from the village of Diouly, the next several villages one passes through are Mouille, Taiba, Ndiaycounda, and Keur Demba. Mouille and Taiba lie on the northern bank of the wetlands while Ndiaycounda and Keur Demba on the southern. These villages have claim to large swaths of land, which accumulate the waters of the Bao Bolon tributary as it moves towards the Gambia River. In 2012 about 80% of the farmers who have claim to plots in the wetland areas used them to farm rice in the villages of Mouille, Taiba, Ndiaycounda, and Keur Demba. This is often coupled with a relay crop of tomatoes immediately after harvesting the rice, using the water retention capacity of the clayey soils to attain a cold dry season tomato harvest in December. These practices are part of a wide-spread and ancient swamp system tradition that is found along the tributaries of The Gambia River all the way through the West African mangrove forests. The Mandinka cultural group, currently a majority in The Gambia is known for their complex rice mangrove systems which integrate tidal control, earthworks and delicate ecological manipulation (Carney 2009). Although the target villages are currently primarily Wolof and Puular speaking populations, the cultural presence of Mandinka practices is evident. The border between Senegal and The Gambia lies only about 21 kilometers to the southeast of the target villages, and long-time cultural and subsistence behaviors are similar throughout this entire area. As rice cropping had fallen out of practice in the region, the heart of the peanut producing area of Senegal, past rice systems are not as evident but their structure is still intact.

The local extension agent working for the *Agence Nationale de Conseil Agricole et Rural* (ANCAR) began extending the rice variety Sayel-108 to the farmers in these 4 villages in 2007. The agent, named Abdoulaye Seck, resides part-time in the village of Katiot (see Figure 4) from where he serves as the agent to the entire Department of Nganda. He is responsible for material and educational extension to 80 villages of various sizes, all primarily populated with subsistence farmers. His predominant rainy season work is to oversee the provision of government issued peanut seed and fertilizer to all of the villages. His other initiatives include nutrition and women’s market garden education. He frequently acts as a trainer and consultant at the Katakel Master Farm site (see Figure 4) implemented and maintained by Fatou Willane in partnership with Peace Corps volunteers (see section 2.2.2).

His method for improved rice variety extension in these four villages is utilization of a community leader who is involved in rice cropping, Mary Diop, to sell the seed at a discounted rate to interested farmers. Over the course of 5 years the number of interested farmers rose from a dozen to over 150 throughout the four villages. Some of these farmers have spaces in the wetlands which become completely flooded and are therefore unused except for rice cropping. Many more have marginally flooded areas where they previously grew sorghum or millet, but now wanted to try rice as well. Another group has land on the very outer margins of the wet lands and began experimenting with growing rice in upland conditions. The farmers who became engaged in these rice growing activities were not only women, as in the past. Many men were intrigued by the possibility of reducing monetary household expenditures on rice. The labor sharing scheme in the rice fields then became very similar to that in other field crop spaces, where men take on specific duties generally related to animal traction. This labor sharing system is closely related to the practices found in rice fields before the peanut boom and shows an attitude shift in the level of importance male farmers are placing on peanut cropping in this area. This renewed focus on rice production is the climate I encountered when first moving to the area.

2.2.2 Master Farm Engagement

In the rainy season (June-October) of 2012 I became well acquainted with the farmers living in the four target villages; Mouille, Taiba, Ndiaycounda and Keur Demba, and those surrounding them. I provided extension services to 16 farmers in their fields of corn, millet, sorghum, and cow peas. Through weekly visits to the field of each farmer I learned a lot about the planting calendars and farming practices in the area, including rice systems. I also acted as a coordinator and consultant at the Master Farm site in Katakel. The Master Farm program is an on-going initiative by Peace Corps Senegal funded by the United States Agency for International Development (USAID) as part of the United States Government's (USG) Feed the Future Initiative (FTF). Peace Corps Volunteers (PCVs) and their leadership identify inspirational and hard-working farmers throughout the country. These farmers enter a contractual agreement with the Peace Corps which dictates they implement certain agricultural and community improvement demonstrations on their land while acting as community educators. In return the farmers are provided with tools, materials, and the guidance of nearby PCVs to achieve these goals (Stoermer 2013).

The Master Farmer and PCVs work together to create demonstration spaces which show the potential of improved field cropping, agroforestry and market gardening techniques. The Master Farmer, PCVs and community members who work in the demonstration space are free to experiment with innovative ideas they feel may improve farmers' quality of life in the area. The several dozen Master Farms are scattered throughout the country therefore on-site environmental conditions such as rainfall and pest population vary. It is up to each Master Farmer to determine what technique will benefit their eco-zone and, in-turn, their community. Peace Corps leadership work with the *Institut sénégalais de recherches agricoles* (ISRA) to be sure the species and variety of crops demonstrated on the Master Farms are appropriate to the climate. PCVs and farmers then choose which agricultural techniques to demonstrate. The fields are open to the community to visit any time to observe and learn these techniques. Large scale 'open field day' training events are held at the peak of the season to disseminate the technologies and mission of the Master Farm on a community level.

I worked on the Master Farm of Fatou Willane in Katakel (see Figure 3) approximately every 10 days for the duration of my 25 months of Peace Corps service. In 2012 I and two other volunteers, Sarah Ferguson and Emily Kraus, assisted Willane in implementing the field crop demonstration plots. Following the guidelines provided to us in a Peace Corps distributed handbook we created demonstrations showing the effectiveness of Integrated Pest Management (IPM) in cowpea, and Conservation Agriculture (CA) in corn, millet, and sorghum. An optional demonstration described in the handbook was for the System of Rice Intensification (SRI). Although the soil on the Master Farm was a sandy loam, not optimal for rice production, we decided to implement the SRI demonstration for the sake of the rice farmers in the neighboring villages of Mouille, Taiba, Ndiaycounda, and Keur Demba. We did not expect high yields but simply wanted to show the nearby farmers how to implement the technique and encourage their interest in the crop. It was not commonly grown but we wanted to empower those farmers experimenting with the crop or looking for improvements to old methods.

On October 6, 2012 an open field day event was hosted by Peace Corps and Fatou Willane at the Katakel Master Farm. A discussion about the field cropping, agroforestry and gardening techniques demonstrated was led by Assistant Peace Corps Director (APCD) Famara Massaly, ANCAR agent Abdoulaye Seck, and Mamort Drame (the son of Master Farmer Fatou Willane). The SRI demonstration inspired a discussion about the potential success of rice production by local farmers. Massaly explained the reasoning behind the increased spacing of the rice plants in the test plots as compared to the control plots. The farmers made it clear they found rice to be an important crop since it is a main dietary staple and discussed that until about 40 years prior many female farmers in the area planted the crop. As I recorded the information of each of the 75 farmers present at the event I asked them if they grow rice or were currently interested in the crop. All of the farmers who reported interest in the crop were from the four villages with access to the wetland area, although not all had field space there.

2.2.3 Local Re-adoption of Rice Production

Figure 5: Community rice education leader Mary Diop giving me a tour of local rice fields in late 2012
Photo by Lorraine Perricone – Dazzo

In order to learn more about the realities of rice farming in these four villages I contacted those farmers who expressed interest at the Open Field Day event. Later in the month, amidst partially harvested rice fields, I met with Mary Diop (see Figure 5). I was taken on a tour of the rice fields in the seasonal wetland area next to the village by her and Babocar Mbaye of Mouille. I learned about harvest techniques, traditional practices and limitations to rice production in the area. Water control was not possible so fields were mostly planted in standing water which ebbs with rain events. Rice plants were established, and rows weeded, by animal traction machine while harvest was done by hand with a sickle. I later ascertained all details about local practices through Phase I of the study, the results of which are outlined in section 5.2.

Diop had been serving as the hub for rice seed, and knowledge, in the four village cluster but explained that she herself did not know very much about the crop. Her husband had died many years previous and she was now financially supported by his brother and her sons. The social status of an elderly widow gives her the freedom to engage in personal projects. She serves as the coordinator of a women's gardening and money-saving group in her village Taiba. The women's market gardening venture is supported by Abdoulaye Seck of ANCAR and he came to know her as a trustworthy and motivated community organizer. She and several other farmers requested seed and training in rice cropping since they had the invaluable resource of the wetlands in their back yard. At their request Seck began to distribute seed using Diop as his connection to the community.

A very small number of farmers had been cropping rice in this area for their entire lives, usually because they had learned the practice as children working on their mothers' fields. Of a sample of 32 farmers who were growing rice in 2012, only 3 had been cultivating the species for longer than the 5 years since Seck had begun extending seed. These farmers cannot be considered early adopters since it was not necessarily a new innovation but in fact an old one. They were simply a very few in the community who had never dis-adopted the previously popular practice. Other villagers did not see rice farming as an option for them. They held the attitude that the few who farm rice do so because they always did and that was simply the way things were. In a society where social and familial structure still holds rigorous prescriptions many people never imagine doing things differently than they currently do. When the change agent did begin to shift farmer attitudes towards a desire to farm rice the few 'born' rice farmers did play the role of early adopters in terms of the diffusion process (Rogers 2010); they were present to educate those interested in the practice and promote their expert standpoint.

However, the most influential change agent in this case was presence of the improved rice seed brought to the villages by Abdoulaye Seck. It is not necessarily the availability of seed itself, since those who never dis-adopted rice know how to save seed and where to buy it. Any other interested farmers could have inquired where to obtain seed as the rice fields are in plain sight and the community is very tight knit. It was, instead, a lack of wide spread interest in rice farming, not unavailability of seed, which limited adoption of the practice. Easy seed acquisition increased interest and subsequently adoption rates. The presence of the seed was only possible because of interest from the true innovators in this diffusion process; the first new adopters like Mary Diop.

The innovators were the farmers who requested that Seck help them increase rice production despite having very little personal experience in doing so. They own land which became completely flooded in the rainy season and was therefore unusable for any other crop at this time of year. Their motivation to request rice seed was obvious, and it was because of this the rest of the farmers became exposed to it. These innovators began seeding fields in the wetlands with rice, which their neighbors took notice of. When they inquired they learned that the seed came from the extension agent, knowledge which legitimized the practice for them; taking it from the marginalized interest of a few to something deemed important by the educated. Each year farmers saw that more of their neighbors were harvesting several 50 kilogram sacks of rice, not a huge haul but enough to save on household expenditures. From the first year to the fifth year of rice extension in these 4 villages the number of farmers with land suitable for rice production who utilized it for this purpose increased from 4.8% to 80%. In fact, the practice became so popular some farmers were planting inappropriate varieties of rice in upland sandy soils which would likely never produce a worthwhile yield. These are the specific conditions which informed my objectives and methods for the data collection activities on the study.

CHAPTER 3

HYPOTHESIS AND OBJECTIVES

My initial interactions with these farmers as described in the last section led to two hypotheses; (1) *rice farmers in the four target villages desire and would benefit from education on improved rice cropping technologies*, (2) *farmer centered experimentation on SRI methods could begin to determine the potential of the system in this area*. To address the first hypothesis I aimed to learn about the current rice systems in place, farmers' motivation to grow rice, average local inputs and yields in rice systems, and attitudes towards adoption of new technologies in the target villages. By fulfilling this first objective I ascertained that an education initiative would be well received. My objectives were then to conduct a community organizing and education campaign which would prepare the farmers to engage in field experimentation.

The goals for the training and experimentation were to; (1) give motivated farmers ownership over extension activities while educating them in field testing methodology and (2) attempt to implement SRI in 3 different ways to determine locally preferable and lucrative adaptations to the system. This second goal included determining whether farmers could raise their yields to approximately 1,920kg/ha. Based on consumption and cropping patterns determined through the survey phase, this yield could eliminate household expenditures on rice for the average farmer. My roles were as facilitator and consultant in the experimentation process while maintaining my place as a resident and community member.

This project was not designed to, nor does it claim to determine if SRI has better yield potential then other BMPs. It aimed to determine if there are possible successful combinations of field management practices, informed by the SRI principles, which could outperform local cropping methods. It endeavored to elucidate on the potential for improved rice cropping practices (in this case a set inspired by SRI principles) to save farmers money on rice purchased for household consumption; and if so whether or not farmers' find the undertaking worthwhile in terms of labor inputs. The objective was to find out if these farmers can continue cropping rice with a similar amount of inputs as their current system but harvest enough to cover household consumption needs.

CHAPTER 4

METHODS

The testing of my two hypotheses can be broken into three distinct phases of which each were informed by the previous. The phases represent time periods and distinct data collection or project development efforts; Phase I was a survey of which assessed local rice cropping practices and attitudes, Phase II was training of farmer researchers in demonstration creation and improved rice cropping principles and Phase III was field based testing of these principles as adapted for each farmers' unique situation.

4.1 Phase I: Survey (November 2012 -March 2013)

I conducted a one-on-one oral survey of current rice farmers in order to test my first hypothesis; *rice farmers in the four target villages desire and would benefit from education on improved rice cropping technologies.* The survey was conducted on 32 famers in 4 villages and contained 80 questions which were coded for ease of analysis. The questions were arranged under the following section headings; Background Information, Assessment of Behavior, Attitudes toward Rice Production and Assessing Current Practices and Knowledge. The final section was broken into the component parts Seed Acquisition, Soil Preparation, Seeding, Field Management, Nutrient Management, Pest Management, Irrigation and Harvest (see Appendix A for full survey). The survey proved that rice yields were low and many farmers were interested in learning how to improve them. It gave me detailed understanding of local systems which allowed me to plan appropriate training and field experimentation which were executed in Phases II and III of this study. These methods are described in sections 4.2 and 4.3, respectively.

4.1.1 Survey Design and Administration

The design of the survey was informed directly by baseline surveys used by the Director of Programming for SRI-Rice at Cornell Erika Styger which she created for her farmer centered research in Mali (Styger 2011). The survey was conducted by me with the accompaniment of the farmer leader Mary Diop on 32 farmers; 11 females and 21 males. The number of farmers surveyed in each village was determined proportionally by population size and prevalence of rice farming in the community and was as follows; 18 Taiba, 9 Ndiaycounda, 2 Keur Demba, 3 Mouille (I originally planned to conduct 20 in Taiba, 10 in Ndiaycounda, 5 in Keur Demba, and 5 in Mouille but was limited by time and number of actual rice farmers in each village). In order to be selected for surveying farmers must have cropped rice for at least 1 year but in some cases they had been farming for over 20 years. Four of the 5 farmers chosen from Keur Demba and Mouille had been farming rice their whole lives and represent about 50% of all the rice growers in these 2 villages. In contrast only 1 farmer surveyed in Taiba and Ndiaycounda had farmed rice for over 5 years but this group of 27 represents only about a fifth of the total rice growers in these two communities.

The survey was conducted orally in the Wolof language and answers were recorded on a paper based questionnaire by me as the conversation progressed. In general, the farmer being surveyed was the only person in the room besides me and Diop but in some cases a fellow farmer or family member would be present and would include their opinion. The process was relatively informal but farmers were explained the purpose of the survey and gave their oral consent to use their responses in this study. The questions were posed as open ended (no multiple choice or scales) and usually led to topics beyond the limits of the pre-planned questions. All of the information given by the farmers inspired the planning of the next phases of the research; Phase II training and Phase III field based experimentation.

4.1.2 Determination of Labor Requirements

Hours per season per hectare used in the results and discussion sections of this study were calculated based on farmers' reports in this survey and field experience I had in Phase III. Farmers were asked how many mornings and evenings were required to execute a certain cultivation action like weeding, seeding or harvest. This was multiplied by how many hours they reported they generally worked on this activity in one morning or evening. This was multiplied by how many people they said would usually work on this activity at a time. This was then divided by 0.4ha since this is the average amount of field space in which these farmers were reporting their labor requirements for. These results are summarized in Appendix D.

4.2 Phase II: Training Series (May-June 2013)

Phase II of this study was an educational initiative where farmers from the target villages were given training. Based on interactions with farmers during the survey process I selected 10 farmers with whom to conduct field experimentation. The selected farmers attended a pre-training event where they were introduced to the SRI principles and field experimentation methods. They then attended a hands-on technical training in improved rice cropping methods. I consulted Abdoulaye Seck (ANCAR), the Master Farmer Fatou Willane and trusted farmer leaders Mary Diop and Babocar Mbaye to assemble the group.

4.2.1 West Africa Food Security Partnership (WAFSP)

These trainings were logistically planned by me and delivered by Peace Corps Program Training Assistants (PTAs) Youssoupha Boye and Arfang Sadio respectively. The content of these trainings was developed through current Peace Corps methods combined with skills we were given at a training-of-trainers event we attended (Arfang attended the French language version in 2012 while Youssoupha and I attended the same training in English in 2013). The training was organized jointly by the USAID West Africa Food Security Partnership (WAFSP), Cornell SRI-Rice, Peace Corps and the Consultative Counsel of Rice Producers' Organizations of West Africa (Jenkins 2013). Here we were given tools and project design insights into conducting education and field research campaigns in SRI with local farmer partners. The most valuable focus of the training for this study was a rigorous analysis of participants' local environments and rice cropping practices in order to adapt the SRI system to farmers' needs. This training exercise, backed by the knowledge compiled in the survey phase, allowed me and the PTAs to tailor training events on the system to my target villages.

4.2.2 Field Experimentation Techniques Training

The first of the training events was held on May 30th in the village of Taiba. The curriculum aimed to introduce the 10 demonstration farmers to SRI practices and principles, and to teach them how and why to setup a visible demonstration. The discussion, led by PTA Youssoupha Boye, began with an explanation of and reasoning behind SRI, including the history and anecdotal results. Using visual aids he explained the six principles of SRI and how they can be executed in the context of the flooded river fields of Taiba. The adaptations of the method included direct seeding and thinning of young seedlings as well as transplantation of young seedlings in wider spacing. Since water control is not an option in this area the farmers were encouraged to plant rice on field spaces which naturally flood and drain with rain events in order to best achieve the temporary flooding recommended by SRI. Incorporation of organic matter and weed residues was also explained.

Following this, Abdoulaye Seck described how an SRI demo is created and how to use them for testing the technique and educating other farmers. Many other farmers from the four test villages were present to hear the discussion and learned how they could support the demonstration farmers. Originally the invitee list was limited to the 10 demonstration farmers but the event was held in a public community space and 33 other curious community members attended. Since the success of a demonstration project also depends on community engagement it was important for other local farmers to understand the project.

4.2.3 Improved Rice Cropping Methods Training

On July 1st 2013 a training of 40 rice farmers from five villages (all four test villages included) was held in the village of Katakel at the Master Farm of Fatou Willane. The 10 demonstration farmers, or one of their family members in their stead, were in attendance. The discussion at the SRI training was led by Arfang Sadio and demonstrations and practice areas were created by Fatou Willane, Lorraine Perricone-Dazzo, PCV Sarah Ferguson and PCV Jessie Maier. Using visual aids, the farmers were taught SRI principles and locally adapted practices. Farmers saw pre-prepared nurseries with and without plastic lining (to improve moisture retention). Sadio demonstrated how to create an SRI nursery using the correct amount of seed and trainees participated in transplanting 11 day old seedlings at a spacing of 25cm x 25cm. The trainers demonstrated using premeasured rakes and a planting string to create SRI grid spacing, two common SRI methods.

4.3 Phase III: Farmer Centered Experimentation (July - November 2013)

I facilitated the creation of field based test plots in order to test my second hypothesis; *farmer centered experimentation on SRI methods could begin to determine the potential of the system in this area*. I wanted to calculate if yields could be raised to 1,920kg/ha or higher while maintaining labor inputs which were reasonable to farmers' schedules. I tracked all farmer activities, inputs, agronomic indicators, labor requirements and yields for 10 side-by-side field spaces which compared SRI adaptations to current practices. The SRI plots were 10m x10 m minimum and I provided each farmer enough seed for 0.5ha.

4.3.1 Peace Corps Seed Extension Program

I desired to create a project which directly tested the hypothesis while fulfilling my responsibilities as a field crop extension agent for Peace Corps. The Sustainable Agriculture sector of Peace Corps Senegal has an on-going seed extension program which provides its agents with improved seed developed by the locally based *Institut Sénégalais de Recherches Agricoles* (ISRA). This initiative, also known as the ISRA Seed Extension Program, compels PCVs to provide interested farmers with small amounts of improved seed for the popular local field crops corn, millet, sorghum, cowpea and rice. The farmers then try the seed in their fields allowing the PCV to visit frequently to take data on certain quantitative and qualitative indicators. Farmers who liked the performance of the seed are then provided with training on seed selection and storage so they can continue to utilize the genetic potential of the improved seed varieties. In some cases the PCV will provide formal training or informal instruction on improved cropping techniques as well. The farmers who try these techniques are known as pilot farmers, and if their spaces are used to educate other farmers they are considered demonstration farmers. The goal of the program is to increase farmers' access to extensively researched improved seed varieties by creating seed sources throughout the country. If farmers learn they like the varieties through these trials, and supply is provided through local farmers' saving and selling of seed surpluses, a closed system of economic advantage that improves local food security will be created.

Many improved varieties of seed need to be combined with altered field management practices to be productive, especially in adverse environmental conditions. These altered field management practices are demonstrated at Master Farm sites (see section 2.2.2) for the benefit of ISRA program farmers and the community as a whole. Peace Corps issues a field crop demonstration handbook to PCVs and Master Farmers to guide them in implementation. The 2012 and 2013 handbook contained a demonstration plan for SRI rice with 3 sub-plots; (1) machine seeded and un-thinned, (2) hand seeded and thinned to 1 plant per pocket at 35cmx25cm spacing and (3) hand seeded and thinned to 1 plant per pocket at 45cmx35cm spacing. Machine seeding results in 35cm-50cm between-row spacing and as small as 1cm within-row spacing between plants. By hand seeding and thinning the demonstrations Peace Corps hoped to show the benefit of fewer plants in more space. Although SRI usually calls for a maximum of 25cmx25cm spacing in the type of soils found on the Master Farm, the 35cm and greater spacing allows animal drawn weeding machines enough berth to pass, reducing labor inputs.

4.3.2 Variety Selection: NERICA-6

One important material input for this study was synthetic rice seed of the variety NERICA-6. The farmers were offered to use this seed in the test plots so that the study could double as part of the ISRA Seed Extension Program for Peace Corps. This was the only variety of rice appropriate for the mixed hydrological system we were working in which was offered by Peace Corps in 2013. The variety is well adapted for the area and high adoption rates are reported in other parts of Africa (Somado 2008). Some farmers also chose to use the seed in their control plots while others used seed purchased from Mary Diop (variety Sayel-108). As part of the local ANCAR seed provision system Diop sells Sayel-108 which farmers have taken to saving or buying new. Almost all rice farmers in the 4 villages were utilizing this variety which had been extended by the program for 6 years consecutively. Even those farmers attempting to grow rice in strictly upland conditions were using Sayel-108 despite it being designed for use in irrigated schemes. The NERICA-6 is an upland variety which can handle some flooded conditions. The quick maturation of the NERICA-6 is ideal for this area of the country where the rainy season can be brief. Rain events are often erratic and the majority of the fields being utilized for experimentation were in marginalized flooded areas fairly well suited for the NERICA-6 variety.

As has been noted earlier, the synergistic effects of SRI affect traditional rice genotypes as well as improved varieties. The demonstration farmers were given the choice to use their own seed but they all opted to use new seed in the SRI trials. Some used it to seed all of their fields. Since they were already using improved seed and not local varieties, the introduction of NERICA-6 was not disrupting long held traditions. Two farmers were particularly interested in the performance of NERICA-6 versus Sayel-108, one of whom implemented a third plot for comparison. I collected harvest data in order to give them insights on the performance of the different varieties and management practices (see Table 2).

‘NERICA’ stands for New Rice for Africa and is a group of as many as 3,000 siblings created at the Africa Rice Center (WARDA) by crossing two species of cultivated rice; Asian rice or *Oryza sativa* and African rice or *Oryza glabberima*. Crosses are facilitated which create offspring containing the best traits of each parent species; typically the high yields of Asian rice and the pest and drought resistance of African rice. These varieties are developed through "conventional breeding methods or through the use of specifically-developed anther culture and there are differences between the many NERICA varieties but they have all been created and researched in order to improve performance in harsh West African environments" (Somado 2008). The first group created, which includes NERICA-6 are all upland varieties, while irrigated rices of the same cross have been created as well. The Peace Corps ISRA Seed Extension Program provided NERICA-6 to its agents in 2013 so this was the variety offered to and willingly utilized by the demonstration farmers in this study.

Seck the local extensionist encouraged me to provide the farmers with the recommended amount of mineral fertilizer for their SRI sub-plots. Most farmers use these chemical inputs but are unaware of optimal rates and safe application methods. The extension agent hoped to use this education and research project as a chance to promote chemical fertilizer best practices. Therefore the farmers were given 2 kg of locally available NPK (6 20 10) fertilizer generally used for ground nut cropping to be applied to their 10mx10m plots and 2 kg of urea to split into 2 applications. Some of the farmers forgot or decided not to apply both treatments of urea. Those who would have normally applied NPK did so in their control plots as well.

4.3.3 SRI Adaptations for Field Experimentation in the Target Villages

From the Master Farm SRI demonstration described in section 2.2.2 and brainstorming sessions during the WAFSP SRI training (section 4.2.1) I outlined three potential adaptations to SRI to be tested in Phase III. The first used the idea of combining machine cultivation and SRI practices through machine seeding and thinning to 1 plant per hill. Three farmers who had experience transplanting their rice tried the second adaptation of singly transplanting rice seedlings at 25cmx25cm spacing, which required hand weeding. Three other farmers elected to try the third adaptation; hand seeding, thinning and weeding. All of these methods were compared in side-by-side plots of the individual farmers' usual cropping method which were machine seeded.

4.3.4 Establishment of Field Experimentation Plots

The machines used for soil preparation, seeding and weeding as well as the animal power to operate them were provided by the farmers. They were asked to bring the amount of manure or compost required of BMPs for rice in Senegal; approximately 2000 tons per hectare. The test plots were all approximately 10m x10m. Most brought all or some of this input before breaking up the soil in their fields by machine and incorporating the organic matter. It is customary to burn all crop residues but I requested the farmers leave all leaf litter or straw in the test plots to be incorporated during soil preparation. Since the fields are used for animal grazing throughout the preceding dry season there was not much litter. Using data collection forms provided at the WAFSP training I recorded all land use history, inputs, labor requirements, seeding and weeding dates, plant development indicators, farmers' comments and general field observations throughout the season (see Appendix B).

Figure 6: Thiendou Willane with an animal traction tool used by most farmers in the Kaffrine Region to prepare soils for planting
Photo by Lorraine Perricone - Dazzo

Figure 7: Babocar Gueye seeding his SRI test plot with a locally purchased animal traction tool
Photo by Lorraine Perricone – Dazzo

I participated in the various necessary crop establishment activities in each field like seeding, transplanting and thinning in order to learn, give guidance and strengthen my relationships with the farmers. My participation also gave me the chance to track labor requirements for the new adaptations such as plot size, number of people and amount of time it took for each activity. Farmers were asked to contact me when they finished preparing their soils by animal traction plough and when they felt rainfall amounts were adequate to begin crop establishment. To space the seeds or transplants properly a 10m length of string was marked at 25cm spacing with strips of colored plastic grocery bag and stretched across the field space. One seedling or 3 seeds were placed at each marker and then the string was moved forward 25cm and the process repeated.

4.3.5 Field Experimentation Plot Maintenance and Harvest

In no case was the field space leveled since no farmer was willing or able to input this amount of labor. After emergence the machine seeded fields were thinned to approximately 25cmx 25cm spacing using a simple hand hoe. This same implement and another similar hand tool were used for precise within-row weeding on both machine and hand seeded test plots. Farmers were asked to report when and how they weeded their plots. I accompanied the farmers to their test plots approximately once every 10 days from July to October to record number of tillers, pest attack, field management actions taken by the farmer and any other crop development observations. I used these visits as an opportunity to connect other interested farmers to the project by showing them the demonstrations and discussing their thoughts on the method. I also assisted on any required labor inputs like weeding and harvesting of grain to remain involved in the process from the field level.

Figure 8: Ndongo Thiall weeding his hand seeded SRI test plot with a typical hand weeding tool used by males in Senegal
Photo by Lorraine Perricone – Dazzo

In order to calculate yield I cut the grain from 5 separate 1m x1m spaces within a sub-plot and weighed the grain after drying indoors for 2 days from each sample. The average of this weight was extrapolated to determine kilograms per hectare per plot. Number of tillers, plant height, number of panicles and number of grains per panicle were also recorded to determine crop performance. Labor requirements were calculated and compared to the labor requirements reported by farmers during the initial survey. Comparisons between crop yields, household expenditures on rice and labor requirements were used to determine if the system has positive or negative potential to increase farmer livelihoods in the target villages.

CHAPTER 5

Results

The three phases of this study showed the test villages to have a rising population of farmers interested in learning how to improve their rice yields and gives evidence as to which practices may achieve this within local conditions. Retaining the utilization of animal traction seeding and weeding tools, combined with improved soil fertility management and the thinning of young seedlings can produce yields high enough to eliminate household spending on rice without increasing labor requirements. Other improved methods like transplantation to achieve uniform spacing can produce yields which exceed household consumption but entail increased labor inputs. The demonstration farmers were educated in field testing methodologies so they are prepared to continue experimenting with altered crop management practices, choosing the amount of labor they are willing to input. Chapters 5 and 6 present the results obtained through the methods already described in Chapter 4.

5.1 Phase I: Survey Results

The survey, which was conducted on 32 farmers in the 4 test villages, painted a clear picture of local rice cropping activities, outcomes and attitudes. A combination of animal traction machinery and hand tools are used to manage introduced rice varieties on small plots located in the flooded wetland area adjacent to the villages. Since rice was recently reintroduced to the area farmers manage their fields of the grass in the same way they grow millet and other grain crops. Their yields are very low, about 1,045 kg/ha and generally do not come close to meeting household needs. Available labor in rice fields is limited as it is not a priority crop, and a bad weather season often means total crop loss. The fields are often attacked by pests as well, most especially birds and blister beetles. Despite these constraints there is rapidly growing interest in producing rice to save on monetary expenditures and with it a desire to learn new techniques to achieve higher yields. The next sections detail the survey results I have summarized in this chapter introduction.

5.1.1 Current Yields

Phase I of this project yielded survey results which elucidated current rice cropping practices and motivations among famers in the 4 target villages. The average size of the household of these farmers is 15 people who consume an average of 64kg of rice per month. This is often purchased as 50kg sacks but many cannot afford the bulk purchase so buy 1-3kg per day. The average monthly expenditure on rice is 18,800CFA or about 40 USD. This means that if the average farmer produced 768 kg of rice they would eliminate household monetary expenditures on daily consumption of rice for the year. (Those who grow their own rice for daily consumption still occasionally purchase Asian rice because it is served at celebrations.) Six farmers reported having reached or exceeded this goal in certain years, but due to unexpected weather conditions these results cannot always be expected. Many had experienced total crop loss due to drought conditions in 2012 while harvesting up to 1000kg from the same plot in other years.

The average size of a plot lying in the heavy and moist soils of the seasonal flooding pattern of the Bao Balong is 1 hectare. Farmers dedicate half or less of this space to rice, an average of 0.4ha. I determined this through the survey and through field measurements. The yields reported by farmers are 1,045kg/ha on average, which would have to be raised to **1,920 kg/ha** to reach the goal of 768kg/ha from the 0.4ha plots, an easily attainable yield in most rice systems (IRRI 2007). The 1,045kg/ha average includes 7 outliers who had been cropping rice for over 7 years, some up to 30 years. Their average yields do not greatly exceed the results experienced by the rest of the sample group who have been cropping rice for an average of 3.2 seasons. The figure of 1,045 kg/per hectare calculated by farmers' reports in the survey is supported by the results of Phase III of this study which compared current cropping practices to adapted SRI methods. The average yield from the control plots of current practices seeded with the variety used by almost all of the respondents, Sayel-108, is 1,041kg/ha.

5.1.2 Rice Establishment Techniques

The survey results paint a picture of the general rice growing techniques implemented by the farmers to produce the yield results described in the last section. Farmers save seed from the previous harvest in mesh rice sack in their hut or storage shed. They do not select individual seed but do sieve out tiny sized grains and store the larger ones. Farmers who did not store seed in a particular season usually purchase 5-15 kg of Sayel-108 from Mary Diop who sells the improved seed on behalf of the local extension agent Abdoulaye Seck. Farmers reported they would like to grow fast maturing and drought tolerance varieties and listed 4 different types of rice grown in the area. Local *glabberima* varieties are called *ceebu honk* or red rice and Sayel-108 is *ceebu weex* or white rice. Many noted a preference for varieties with long and large grains like NERICA-6. Other preferred traits are tall plants and those easy to process in the mortar and pestle. *Glabberima* varieties tend to shatter during processing while crosses like NERICA and Sayel-108 do not and farmers noted that the introduced varieties were preferred for this reason as well.

Upon the first large rain events in July soil preparation begins. This process consists of burning all remaining residues and breaking up the soil surface with animal traction ploughs (see

Figure 6), often doing 2 passes perpendicular to each other. The soils in the farmers' fields range from alluvial clay loams in the flooding pattern to ferruginous loamy sands grading up the slope. 5 farmers said they had completely upland conditions while the remaining 27 have field spaces with a mixed hydrological environment. The most common field space becomes flooded after large rain events and late in the rainy season. Sixty five percent of farmers said they always applied some manure to their soils. Other farmers said they do not usually have enough manure to apply to all their field spaces and since rice is not a priority they may not reserve any for it. Rates of application were very low only averaging 200kg per hectare. This organic matter (OM) is brought to the field by an animal drawn cart previous to soil preparation so it may be incorporated. A major focus of the curriculum used in the training phase (see sections 4.2 and 5.2) was the importance of OM inputs, as the current soil fertility management practices are inadequate for good rice yields.

After the soil moisture level is deemed adequate by the farmers they seed their rice fields, generally the 3rd or 4th week of July. All but 2 farmers who were surveyed reported that they seed by machine using a disc designed to properly space corn seed. Since the holes in the disc are large enough for 2 or 3 corn seeds to pass through they allow 10 or more rice seeds to pass through which creates close within-row spacing. Some farmers mix the rice seed with NPK fertilizer or soil in the hopper to more evenly distribute the seed within-row. Farmers are accustomed to creating 45cm between-row spacing with their machines for larger field crops like corn and millet so they generally do the same for rice. This spacing is too large for rice especially in poor soils which may be one explanation for their low yields. 75% of farmers said they thinned their within-row spacing to 10cm with a hand hoe at about 22 days after planting to an average of 3.5 plants per hill. Others cited the reason they do not thin is that short rice plants do not need to be thinned and that dense within-row spacing reduces weed competition from the wide between-row spacing.

Seventy percent of farmers reported some use of NPK or urea mineral fertilizers in their rice fields. Those who use NPK apply low rates and generally apply by broadcasting within a few days after planting (DAP). A few others apply NPK between 15 and 30 DAP at the same time they side dress with urea. The fertilizer use rates of the farmers in the target villages was often a compromise between recommended practices and what the farmer could afford in money and time. Many more are simply not aware of proper application rates and methods. Weeding is done between 3 and 5 times per season and usually consists of animal traction machine weed removal from between the rows followed by precise hand hoe weeding within-row. Generally by time the reproductive growth cycles has begun 50-60 DAP the fields are constantly flooded and weeding is impossible.

5.1.3 Harvesting Method

Harvest of grains is done by cutting the entire rice plant down with a scythe or knife and stacking them in bundles in the field to dry. These bundles are then beaten with curved sticks until all the grain has fallen off the panicles. Winnowing is done by pouring the entire contents of the pile such that residues and empty grain are carried by the wind and filled grain is lands in a bowl. Grain is then stored and processed in a mortar and pestle daily or weekly as needed for household consumption. There is a rice grain processing mill in the nearby village of Katiot (see Figure 4) and others to the south in The Gambia (see Figure 2). Farmers can pay a percentage of their harvest to have their grain milled. Only two farmers surveyed said they have utilized this service as it is usually not worth the payment required. The rice straw residues are fed to the donkeys and horses which draw the machinery.

5.1.4 Summary of Labor Requirements

Table 1 shows a breakdown of the labor requirements for the field actions just described as reported by the 32 farmers surveyed (the breakdown of how these numbers were determined is in Appendix D). This division of labor is the same for all field crops grown in the area whether the field is owned by a male or female member of the household. Soil preparation, seeding and weeding by machine are necessary in all fields at around the same time. This means that if a man does not find a certain field space or crop to be a priority he may not be able to perform these necessary duties in optimal time for plant development. This is an issue with all crops in the area not just rice. Of the male farmers surveyed the majority were speaking of rice cropping activities they elected to take on in their own field spaces, while the rest were speaking from experience in the fields of their mother or wife.

Not including the time it takes to process the rice for consumption, which is done daily, farmers dedicate 254 hours to farm their 0.4 ha plots in one season, or 634 hours/ha. Most reported that this is the amount of time they are willing to dedicate to rice cropping activities but would consider increasing the amount if the yields were substantially higher. The group as a whole has little reservation about the value of the time they are putting into rice cropping activities. The results of the survey show that there is rapidly growing interest in rice farming in the area.

	Soil Preparation/ OM Application	Seed by Machine	Weed by Machine	Within-row Weed and Thin by Hand	Harvest	Thresh	Winnow	Process for Consumption
Man hrs/ha/season	40	12.5	15	95	332	20	120	261
Performed by	Men/boys	Men/boys	Men/boys	Women/girls	Everyone	Men/boys	Women/girls	Women/girls

Table 1: Labor Requirements for Cultivation Under Local Rice Cropping Practices in the 4 target villages (per hectare per season)
By Lorraine Perricone – Dazzo

5.1.5 Constraints to Rice Production

The average rice farmer from the target village established and maintained their rice field as described in sections 5.1.1-4. When asked directly and indirectly farmers generally reported that their greatest challenge to growing rice was a lack of material inputs most especially new machinery, fertilizer and seed. This was followed by a lack of labor both human and animal for weeding and harvesting the rice fields. The third most commonly reported challenge to rice growing was technical knowledge such as pest and water control. Another constraint, mostly reported by female farmers, was the time needed to process the rice for consumption. Since imported rice is usually purchased already hulled and polished it is a much faster and easier meal to prepare than millet or local rice. When preparing local rice they need to hand tap it in mortar and pestle to remove the hull and possibly the bran for an average of 15 minutes per kilogram. This increases the prep time of rice dishes by as much as 45 minutes per day for women.

Farmers mentioned a lack of seed and fertilizer inputs but these are both locally available and subsidized. Their answers may have been biased as they assumed my associations with Peace Corps and ANCAR meant I could provide them with free inputs. Farmers know the type of program I represent often brings seed and fertilizer but likely would not provide animal or human labor inputs. I was careful to be clear that any small inputs I provided to the demonstration farmers in Phase III were not payment or a hand-out but materials needed for experimentation to benefit the community as a whole. Providing enough feed for large animals, which are used for seeding and weeding all field crop spaces, is in fact a very large challenge in the growing season. Finding enough human and animal labor to spread across all of their fields in the short rainy season is difficult. This is the reason, as shown by the survey, most rice plots are less than 1ha and receive relatively minimal labor inputs.

The most commonly reported insect pest issue is with *C. Purcaticollis F*, a species of blister beetle which feed on the rice plants as they flower causing unfilled grains. Most respondents also noted issues with termites which are known to attack the stems, leaves and panicles of rice plants during dry periods (Heinrichs 2007). Many people also reported that small white moths cause damage to their rice panicles. The farmers observe loss of grain in their fields around the same time there are many of these moths passing through so they assume the moths have done the damage. I believe the moths are actually a beneficial species of Lepidoptera feeding on some other insect pest which damages the rice plants (Heinrichs 2004).

Forty-four percent of respondents use chemical pesticides in their fields none of whom could report the exact name of the product or chemical they used. Most purchased unlabeled liquid or powder pesticides from a local market. They had little to no knowledge of safety or efficacy in usage of these products and it is likely they were applying them after pest population pressures were too high. Rotting of stems and roots of the rice plants is also a major issue. Almost all farmers reported that late in the season they would have to station children in their rice fields to yell ‘ha ha’ to scare off birds.

Figure 9: Blister beetles in the field of Mordu Seck. These pests fed on all rice plots but did more damage in the fields seeded with the rice variety Sayel-108 as compared to the variety NERICA-6.
Photo by Lorraine Perricone – Dazzo

5.1.6 Attitudes Toward Rice Production

Eighty-four percent of respondents said they increased the amount of land and time they dedicate to rice cropping in the past 5 years, while the other 16% stayed the same. Forty-two percent of those surveyed had tried another new agricultural practice in past 5 years along with rice cropping, 65% of whom learned it from a fellow farmer. The other 45% of innovators learned new agricultural techniques from an extension service or NGO farmer education program. All respondents said that rice cropping should be increased in their area and cited home consumption or money savings as the reason. All respondents are rice producers but 90% reported millet or corn as the most important crop they grew. The second most important was peanuts on average but many farmers expressed strong attitudes against the importance of peanut cropping. They felt selling their peanut crops was not as lucrative as it once was and that farmers should begin focusing their energy elsewhere. It still remains that corn, millet and sorghum are used to make *cere*, a local ‘cous-cous’ which is eaten at least 2 times per day, the third meal being rice based. Further, even if farmers deemphasized their peanut production to just the subsistence level they would still need to produce enough to consume daily as it is an important source of protein.

They all also said they utilize the rice they grow for home consumption and only the rare surplus is sold. While all farmers find dedication to rice cropping important only 47% claimed to be knowledgeable about the practice. Most reported that there was a lot for them to learn about rice cropping and that they were currently just experimenters. When asked who in the community was knowledgeable about rice cropping most respondents mentioned Mary Diop and Mat Mbaye of Keur Demba. This final survey result led directly to the conception and design of Phase II, technical training on improved rice cropping and field experimentation techniques. The survey aimed to determine what farmers knew, and didn’t know, about successful rice cropping. The training events aimed to fill these knowledge gaps as well as build the capacity of the farmers to fill these gaps themselves through experimentation.

5.2 Phase II: Training Initiative Results

Figure 10: Farmers learning about SRI principles at a Peace Corps led training event in June 2013
Photo by Lorraine Perricone - Dazzo

The training events described in section 4.2 reached the demonstration farmers and at least 50 members of the wider rice cropping community. This resulted in increased interest in the SRI technique and transparency to the experimentation activities conducted in Phase III, described in section 4.3. The first training was led by well-respected Peace Corps and ANCAR leadership which brought clarity to the goals of the project and lent credibility to my consultancy and guidance. The demonstration farmers began coming up with ideas and plans for field experimentation. By hosting the second and larger event at the Master Farm site the community is now conscious of a long term knowledge source on the subject; the community educator and Master Farmer Fatou Willane. The event was valuable for the demonstration farmers who created field tests in Phase III as it helped reinforce their understanding of the system through discussion and practice. The demonstration farmers had chosen the adaptation of the method they wished to try out and a seeding schedule was coordinated at the close of the events. All 10 demonstrations were prepared and seeded within 2 weeks. Other area farmers were given the knowledge and practice to develop SRI in their fields as well. Besides the farmers who piloted the SRI adaptations as part of this study at least two others in the target villages implemented SRI principles in 2013.

5.3 Phase III Farmer Centered Field Experimentation Results

This section briefly describes the main outcomes of the field experimentation phase of the study. The following sections give details of the individual results of each establishment technique.

Farmer (Village)	Plot	Seeding Technique	Spacing (within-row cm x btwn row cm)	Variety	Yield (kg/ha)	Man Hours*
Babocar Gueye (Mouille)	SRI	Machine	20cm x35cm**	NERICA 6	2940	634
	Control (a)	Machine	5 x 35	NERICA 6	1,640	634
	Control (b)	Machine	3 x 35	Sayel 108	900	629
Thiendou Willane (Ndiaycounda)	SRI	Transplant***	25 x 25	NERICA 6	1,530	747
	Control	Machine	17 x 35	NERICA 6	1,810	634
Keba Cisse (Taiba)	SRI	Transplant	25 x 25	NERICA-6	2,440	792
	Control	Machine	2 x 45	Sayel-108	463	629
Mary Diop (Taiba)	SRI	Transplant	25 x 25	NERICA-6	2,620	792
	Control	Machine	5 x 45	NERICA-6	1,540	634
Mat Mbaye (Keur Demba)	SRI	Hand****	25 x 25	NERICA-6	3,450	782
	Control	Machine	4 x 35	Sayel-108	1,760	634
Mordu Seck (Mouille)	SRI	Hand	25 x 25	NERICA-6	2,610	782
	Control	Machine	4 x 38	NERICA-6	1,160	629

*Man hours are based on a calculation of hours required to prepare soil, seed and weed one hectare of rice under the different techniques, see Appendix D.
** Thinned within row with a hand hoe at 8-12 days to 1 plant per hill
***Singly transplanted seedlings at 8-12 days old at 1 plant per hill
****2-5 seeds placed by hand

Table 2: Farmer centered field experimentation results. This figure summarizes the techniques and outcomes in Phase III; the field experimentation.
By Lorraine Perricone - Dazzo

Yield Needed for Self Sufficiency: 1,920 kg/ha	Desired Labor input of famers: 634 hrs/ha		
Technique	Yield kg/ha	Labor Requirements (hrs/ha/season)	# of plots
Hand seeding + wide in-row spacing	3,030	782	3
Machine + wide spacing	2,375	632	2
Transplant singly + wide spacing	2,196	792	3
Machine + narrow in-row spacing	1,244	629	5

Table 3: Average yields and labor requirements of rice establishment techniques in the target villages By Lorraine Perricone-Dazzo

The field research phase of this study showed that the average yield for rice machine seeded with wide in-row spacing exceeds the goal yield without increasing labor requirements. The goal yield is 1,920 kg/ha and represents the average required output farmers need to eliminate household spending on rice for consumption. The yield is raised 91% from 1,244kg/ha under the current technique to 2,375kg/ha under the improved adaptation. This result is especially distinct when the SRI principle of wider spacing for younger seedlings is integrated. In order to adapt this principle to a machine seeded field, hand-thinning of the rice plants is required. The majority of farmers thin as part of their current practice but to achieve the goal yield the thinning method must be altered in 3 ways; (1) increase the space between plants to approximately 25cm, (2) leave only 1 seedling per hill and (3) thin between 8-13DAP. The spacing achieved through the hand-thinning method is not exact and between row spacing will be 35cm at the least due to the turning radius of the machine seeder.

More precise spacing achieved by direct seeding by hand increased yields a further 53% to an average 3,030 kg/ha. This technique required labor inputs of 782 hours per year which exceeds most farmers' desired amount of 634 hours per hectare per year. Transplantation of seedlings cared for according to SRI principles increased yields to 2,196kg/ha which meets the target goal but is exceeded by both direct seeding methods in some trials. Transplanting also increased labor to 792 hours per season per hectare, the highest labor requirement of all the adaptations.

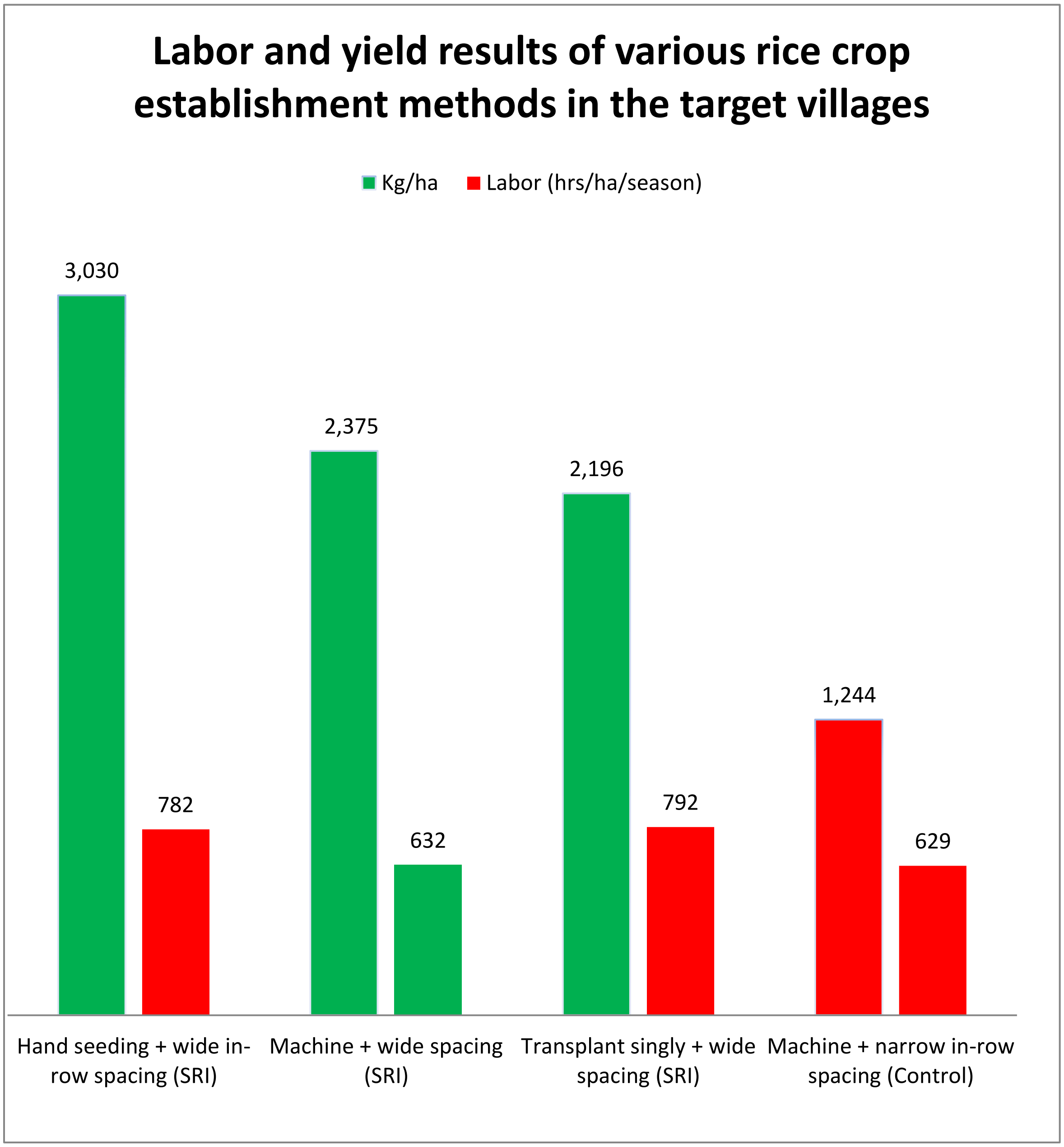

Figure 11: Labor and yields from 4 different crop establishment methods. The results which appear in green reached the target requirements of farmers while those in red do not. All new combinations of techniques exceed the control in yields but only the machine seeded treatment also keep labor requirements low. By Lorraine Perricone - Dazzo

The lowest yields came from fields planted with the variety Sayel-108; the control plots of Gueye, Mbaye and Keba Cisse. Although none of these plots applied improved spacing the average yield of plots established with the same technique but seeded with NERICA-6 was 1,446 kg/ha versus the 1,041 kg/ha produced with Sayel-108. This is almost exactly the same as the yields reported by farmers in Phase I from fields seeded with Sayel-108 for the past 5 years; 1,045kg/ha. Further discussion of the adaptations as they were managed by the individual demonstration farmers in the unique environments of their field spaces is necessary to clarify these yield results.

CHAPTER 6

DISCUSSION OF PHASE III

In this section the results of each treatment will be discussed with a focus on individual farmers and environments, starting with the transplanted plots. One main variation among the field spaces were hydrological conditions which are summarized visually in Figure 20.

6.1 Transplanted Adaptation

Three farmers transplanted 8 day old seedlings from field side nurseries into the test plots at 25cmx25cm spacing. Two of the three (those of Mary Diop and Keba Cisse) were transplanted from the same nursery into similar low-land conditions while the third (Thiendou Willane) was located in a marginally flooded space. The nurseries were established according to SRI standards extended during the training phase. Seeds were soaked for 24 hours to induce pre-germination before being spread into an amended and bunded nursery bed, carefully so as not to have seeds touching. This is so seedling roots have ample space to develop. Farmers watered their nursery daily from rain water accumulated in the flooded pattern nearby their fields (see Figure 12). The NERICA-6 in both nurseries exhibited strong seed vigor and were ready to be transplanted at 8 days old. All three SRI plots were transplanted the same way using a planting string marked at every 25cm. All of their corresponding control plots were seeded using a machine (see Figure 7).

Figure 12: Thiendou Willane and Penda Ndiaye preparing a nursery. The seasonal flooding can be seen starting in the background. It will later inundate the entire field during large rain events for one or two days. This hydrologically marginal field space performed better under machine seeded and thinned than transplanted crop establishment
Photo by Lorraine Perricone - Dazzo

Figure 13: Preparing the saturated soils in Mary Diop’s field for transplanted seedlings.
This lowland field space will become intermittently inundated for up to 3 weeks during the rainy season
Photo by Lorraine Perricone – Dazzo

Mary and Keba's transplanted test fields had similar yields which outperformed their corresponding machine seeded control areas. Their soil was heavy and consistently wet throughout the season which may have given the young seedlings the time and space to produce the physiological reaction SRI hopes to achieve. The within-row spacing of rice plants in their control plots was very dense (as many as 30 plants per meter) and susceptible to blister beetle attack which severely lowered the yields in these spaces. Their plots exhibited the lowest land conditions of the entire study which consistently flooded throughout the rainy season for up to 2 weeks at time. This deep flooding may have contributed to yields lower than the hand seeded plots (described in section 6.2) despite them having the same spacing scheme.

Figure 14: Side-by-side view of Keba Cisse's transplanted SRI plot (upper right) and machine seeded control (left and foreground). The within-row spacing of the control plot is very close while the SRI plot is made up of widely spaced, singly transplanted individuals.
Photo by Lorraine Perricone - Dazzo

The third transplanted field, of Thiendou Willane, did not have the same water control issues but had lower yields than the hand seeded fields and its own machine seeded control plot. This leads me to infer that it was not only over inundation of water that limited yields in the transplanted plots of Mary and Keba, but shock to the seedlings at transplantation as it was likely in this third field. Rain events were sporadic during the first few weeks after transplantation which may have put environmental pressures on the young seedling. Direct seeding by hand or machine outperformed transplantation in all trials of this study except the control plots which had very close within-row spacing. This is true in trials both upland and lowland.

In contrast Willane’s control plot, which was machine seeded, outperformed the transplanted test plot. The drought pressure on the young seedlings may have severely reduced potential in the shallow flooded zone. He cleverly found a way to adjust his mechanical weeding attachment to remove weeds from within the 25cm spaced transplanted field. Using this tool farmers are able to remove weeds, aerate soils and incorporate some of the weed residues into soils. This is all part of regular SRI practices which the other transplanted demo farmers were implementing using just a hand hoe. Willane did have to wait until plants had reach a certain height to machine weed so as not to damage them but his field was consistently weed free. Despite this effort the transplanted plot did not have a very successful yield.

The real success was in his machine seeded control plots where he thinned his within-row spacing to an average of 17cm, his usual practice. He mixed NPK and soil into the seed hopper to increase the within-row spacing of his rice plants. The SRI trial had an equal amount of NPK applied. His practice of spreading out the within-row spacing proved successful. His widely spaced machine seeded control plot was established more like the machine seeded control plots and the yield from this plot is factored into the average of these treatments (see Table 3). It was still 390 kg/ha lower than the goal yield but exhibited the same impressive plant development as the plants in Babocar Gueye and Moussa Cisse's fields.

The lowland machine seeded and thinned field of Babocar Gueye had a higher yield than either Mary or Keba's successful transplanted fields. The result of the transplanted trials show that those farmers who have adequately clayey lowland soils can improve their yield through transplanting as opposed to their traditional method, but machine seeding with wide in-row spacing can outperform transplanting in both upland and lowland applications.

6.2 Hand Seeded Adaptation

Three farmers (Ndongo Thiall, Mat Mbaye and Mordu Seck) chose to seed their field by hand at about 2 seeds per pocket at a 25cmx25cm spacing. After adequate rainfall and field preparation the test plots were seeded by the farmer, me and several of their family members. Thiall and Seck both pre-germinated their rice seed by soaking. Although this practice may aid in crop emergence it does require continuously moist soils after seeding. In case that rainfall wasn't adequate to maintain soil moisture Mbaye decided not to soak his seed. He also utilized a seed selection method taught at the training events; rice seed is placed in a saturated salt solution and any floating grain is discarded so that only the heartiest seeds are planted. All the other demonstration farmers performed this exercise but with regular water instead of a salt solution.

Ndongo Thiall of Taiba had a test area of hand seeded 2-per pocked NERICA-6 which suffered almost complete defoliation by grazing cows at 40DAP. Although the plants were able to reestablish and produce panicles, they were weakened and suffered complete crop loss from birds and grasshoppers. The establishment of his plot gave important labor requirement data for the hand seeding method.

Mat Mbaye's hand seeded test plot produced the highest single yield from one space, likely due to the security from inadequate rainfall which direct seeding provides and the perfect spacing achieved through hand placement. Mbaye is also an extremely diligent manager of his field crop spaces. Despite his success with hand seeding the machine seeded test plot of Babocar Gueye produced a higher yield than the hand seeded field of Mordu Seck. This showed that improved spacing achieved through thinning as opposed to hand seeding can produce comparable if not better yields. Despite this, on average the hand seeded trials still exceeded any other adaptation. The three farmers and their family members who hand seeded their test fields pocket-by-pocket said they would likely never use that technique again despite the better result; it is simply too labor intensive. Besides the long hand seeding process routine weeding has to be done exclusively by hand as the rows are too narrow for the animal traction machinery to pass through. This gives farmers the opportunity to incorporate weed residues which increase organic matter but with higher labor requirements than using the machine.

Figure 15: Hand seeded treatment of Mordu Seck. Precise 25cmx25cm spacing produced healthy plants which lost much less grain as the neighboring control plot to pest attack. Incorporation of weeds into the soil in this plot also deterred termites.

Photo by Lorraine Perricone – Dazzo

Termite infestation was observed in the field of Seck but little damage was done to the actual rice plants as they fed on the incorporated weed residues instead. Termites were reported as one of the worst pest pressure on rice in this area in Phase II and this SRI technique protected rice plants in this case.

Although these farmers do not think they would hand seed again they reported being impressed by results of wider spacing in rice as compared to their traditional method. Mbaye's control plot had a desperately low yield which is likely due to the very crowded within-row spacing in this field as well as variety choice of Sayel-108. In final assessment interviews with Seck and Mbaye they both said that they would try to achieve improved spacing using the less labor intensive method of machine seeding and thinning which they saw implemented in the field spaces of Babocar Gueye and Moussa Cisse. This involves small modifications to their current system, like making closer turns with the seeder between rows.

Figures 16 and 17: Higher numbers of tillers were achieved by plants with wider within-row spacing (below) as opposed to cluttered (above) in Mat Mbaye's fields.

Photos by Lorraine Perricone - Dazzo

6.3 Machine Seeded Adaptation

Three farmers (Babocar Gueye, Penda Ndiaye and Moussa Cisse) seeded their fields by machine and then thinned the result to approximately 35cmx25cm. The over-all conclusion drawn by this study is that this adapted technique can meet the desired yield and labor inputs of farmers in the target villages. This conclusion is drawn from exact calculations of labor inputs, yield measurements from the test field of Babocar Gueye and the control field of Thiendou Willane, and qualitative observations of crop development and farmers' field activities.

Moussa Cisse of Taiba also maintained machine seeded test and control areas of NERICA-6 but they were established in August and I was not able to calculate yield data before the end of my Peace Corps service in early November. I did conduct field observations of his test plot for two months which exhibited impressive plant development. I am able to project his yield by comparison to other similar treatments based on number of plants per meter squared and average number of tillers and panicles per plants. Without unforeseen pest attack or other crop destroying circumstance his plot certainly exceeded the goal yield reaching at least 2,600kg/ha. I did not include this approximation into the cited yield average for machine seeded and widely spaced plots. I extrapolated the number just to produce evidence that the test plot was likely successful.

Figure 18: Animal traction seeder hopper attachment. Rice seed mixed with soil to reduce within-row plant density when seeding with a disc designed for corn.
Photo by Lorraine Perricone – Dazzo

Babocar Gueye and Moussa Cisse used a disc for seeding corn to disperse a mixture of soil and rice seed in 15m long rows spaced as closely as the machine would allow at 35cm. They used low rates of NPK fertilizer in all treatments. Crop emergence created about 4cm within-row spacing which we thinned by hand to 1 plant per hill and approximately 25cm spacing. We held a 25cm long stick as we went along in order to approximate spacing as we thinned. Weeding was done by animal drawn implements between rows and hand weeding was done within-rows. This requires much less labor than hand weeding the entire field. The SRI prescription of incorporating weed residues during this process is easily achievable using these implements. I simply encouraged farmers not to discard the weeds but to leave them in the soils, actually reducing labor requirements. This method served to curtail termite attack, added organic matter and oxygen to the soils and provided mulch between rows. This altered weeding method was implemented in all of the test fields but only actually saved labor in the machine seeded adaptation.

The machine seeded plot of Babocar Gueye was in lowland conditions and outperformed the transplanted trials in the same conditions. The machine seeded plot of Moussa Cisse was adjacent to the transplanted fields but in a slightly shallower grade of flooding. It was exposed to the same blister beetle pest attack which may have reduced NERICA-6 yield in the transplanted trials but had better plant vigor in spite of it. I believe the difference in outcomes is because of pressures put on the plants during transplantation which reduced their over-all performance. The machine seeded method provides security in conditions where rain events may be erratic.

Figure 19: The spacing in the machine seeded and thinned fields are not as exact as the hand seeded fields which is reflected in the yields. Despite this, the amount harvested from this field was adequate to cover annual consumption of rice for the farmer.
Photo by Lorraine Perricone – Dazzo

The control plot of Thiendou Willane was on higher ground with less water accumulation than the test plot of Moussa Cisse and it showed the same improved results with the same technique. Willane is an innovative farmer who has noticed the benefit of wider spacing of his rice and integrated it into his usual practices. The farmers were asked to crop rice how they normally would in the control plots, which for him meant thinning the within-row spacing. He did this using the technique most farmers in the area use for millet; remove 20 day old plants with a hand hoe to about 15 cm spacing with 2-4 plants per hill. It was the similarity between this treatment and the machine seeded SRI adaption which prompted me to average his results in with those of Babocar Gueye to determine the potential of the system. The harvest did not reach the goal yield but evidence from Gueye's plot supports that if Willane had thinned to 1 plant per hill and a slightly wider spacing his yield would have reached the goal. His results were markedly better than transplantation in the same exact field space, showing that direct seeding and wider spacing improves yields in all the hydrological gradients tested in this study. As there is less water in this zone yields were lower than the trials in wetter zones, but still improved by the machine seeded and thinning method. This adaptation is the only one tested that both meets the target yield and does not exceed the amount of labor these particular farmers can dedicate to rice cropping.

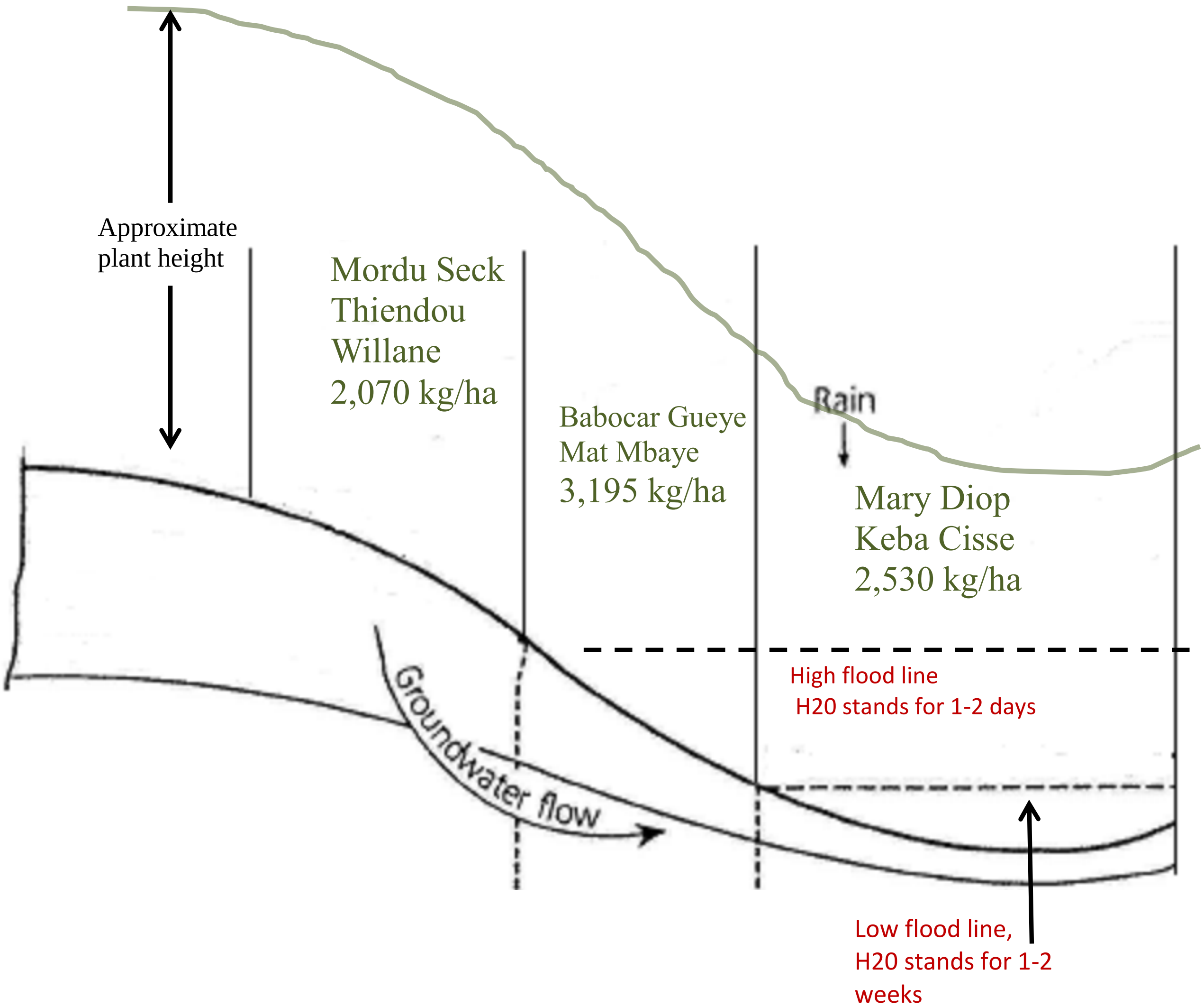

Figure 20: Flooding depth throughout the rice cropping fields of the demonstration farmers and average yields of NERICA-6 in the SRI plots in these conditions
Source: Modified by Lorraine Perricone – Dazzo from
http://www.fao.org/docrep/003/x6611e/x6611e03a.htm

CHAPTER 7

FURTHER DISCUSSION

The last sections have explored why certain techniques and test plots were successful while this section makes recommendations to farmers and future research which should be considered. This paper has focused heavily on the effect of spacing and labor availability on rice yields in the target villages. Variety choice, soil fertility, pest management and hydrological conditions will now be expounded upon as these are also main factors effecting good rice yields in the target villages.

7.1 Variety Choice

The NERICA-6 variety produces higher yields and responds better to the local environment than the popular variety in use Sayel-108. In final interviews with the farmers they each reported a preference for the NERICA-6 variety. They cited the yield increase and the plants' high stature which results in more rice hay to feed their animals. The NERICA-6 also resisted pest attack better than Sayel-108; beetle and bird attack were evident in NERICA-6 test and control plots but crop loss was less than in neighboring Sayel-108 plants in all cases. A panicle analysis at harvest showed that the NERICA-6 plants had larger and more filled grain per panicle along with more panicles (See Appendix E). At the height of the rainy season the transplanted fields of Diop and Cisse became completely inundated for over 2 weeks but the stature of the NERICA-6 variety allowed the plants to continue to photosynthesize and survive. Large swaths of Cisse's control area planted with the shorter Sayel-108 were wiped out during this flood, along with neighboring fields of the same variety. This was only an issue in the fields lying in the lowest points of the flooding pattern (see Figure 20).

All treatments of Sayel-108 were extremely closely spaced within row which most likely limited panicle production, which was an average of 4.5 per square meter as opposed to 9.2 in fields of the same treatment but planted with NERICA- 6. It is possible that the Sayel-108 variety would react better to wider spacing but farmers who have used the variety for years do not recommend increasing within-row spacing. They report that short varieties like Sayel-108 are purposely not thinned because its narrow canopy is conducive to crop destroying weed pressure. This means that in order to maintain wide spacing with Sayel-108 weeding labor time would increase substantially.

Using this short variety in the more frequently flooded fields like those which were transplanted in this study may alleviate weed pressure caused by wider spacing, but in the case of Cisse's control plot the depth of the water exceeded the height of the Sayel-108 and cause irreparable damage while inviting pest attack and fungus. The performance of the NERICA-6 was 28% better than Sayel-108 even without any changes to crop management, though still about 500kg shy of reaching the minimum yield for farmers to eliminate rice purchases. This is likely because of the significantly lower amount of grain and grain weight per panicle on Sayel-108 plants as opposed to NERICA-6 (see Appendix E). This proves that adoption of the variety is beneficial even without the adoption of improved spacing, but both must be used to reach the goal yield.

There was no resistance from farmers in the sample villages to use the new variety. Farmers in the area were already willingly utilizing improved varieties and were even eager to try the NERICA-6. Farmers who harvested the NERICA-6 in 2013 may choose to sell or share seed rice they have stored. Farmers plant 0.4ha on average so seed requirements are generally low. Farmers in the area will likely request seed from the local PCV and ANCAR agent in the future. These development workers could encourage experimentation with other appropriate NERICA varieties. The rice farmers in the target villages work in various hydrological conditions which range from 4 feet to no standing water at any point in the season. A local knowledge bank of which seed to use in each of these conditions is common in rice cropping areas and will likely develop as rice systems become re-engrained in the target communities of this study.

7.2 Soil Fertility

The benefits of organic matter inputs were covered in depth at the Phase II training events. Further training on mineral fertilizer usage guidelines and safety is necessary among the rice farmers of the target villages. Usage of mineral fertilizer was integrated into the demonstration phase in order to give clarity on rates and timing of usage. This education benefitted the 10 farmers involved but may not have reached the wider community. The visually obvious differences in crop management like seeding method and spacing were readily perceived by the community. Knowledge of other actions which took place in the test plots like properly timed fertilizer applications were not as easily diffused. Farmers were instructed to apply NPK they purchased on their own in the control plots, while rates and timing were regulated in the test plots. Emphasis on the long-term benefits of organic matter inputs is necessary if rice education in these villages continues. The easiest way to increase OM inputs is to refrain from burning crop residues each year. This may also be combined with weed residue incorporation discussed in section 6.3.

Rapidly changing environmental factors have contributed to the salinization of the flooded pattern in which this study took place. The test plot of Penda Ndiaye suffered total crop loss due to salty and nutrient poor soil conditions. She practiced relayed cropping of rice and tomatoes in this same space for 5 consecutive years without rotation, proper organic matter inputs or fallow. Deforestation of the area caused the water which usually flows several dozen meters away from her field space, to erode her top soil as well. Residue burning contributes significantly to soil depletion in this area. General education campaigns on reduction of this practice are direly needed in the target villages. The test fields with the highest yields had richer soils which had been fallowed or received continuous organic matter inputs like the fields of Keba Cisse and Mat Mbaye (see plant analysis in Appendix C for comparison).

7.3 Pest Management

Pest identification and control methods were not included in the training phases of this study. Common rice pests observed in the fields throughout the experimentation phase were termites, blister beetles, grasshoppers and birds. According to the survey over 50% of the rice farmers in the area use chemical pesticides (the type of which they are unable to identify) in their fields but only 1 of the 10 demonstration farmers used any chemical product on the test fields.

Mat Mbaye applied a liquid pesticide with a small pump sprayer backpack twice to both his SRI and control plots. He hoped to reduce populations of blister beetles which suck the liquid from developing rice causing unfilled grain. Although both fields were sprayed, panicle analysis showed a much higher rate of empty grain in his plot of Sayel-108 than his NERICA-6 SRI plot. The yields in his SRI and control plot were higher than those from any other of the same method and variety combinations, perhaps due to the usage of pesticides. He did not know the name of the product he used. He had purchased the unlabeled chemical on the recommendation of a salesman in the weekly market. Safety precautions such as attire and field reentry time regulations were not observed by him or his family. Education on appropriate usage and safety methods would benefit both rice yields and farmers' health.

Organic pest control methods were implemented by some of the demo farmers throughout the season. Babocar Gueye strung thin strong metal wire between two trees in his plots which created a loud whirring sound in the wind. This deterred birds, rodents and canines from eating or digging in his field. Theindou Willane burned piles of millet chaff between rice plants to create a smoke which deters flying insects. Farmers in the area commonly burn rubber tires for the same effect. The types of innovations observed in the demonstration farmers' fields could be integrated into future training. Fields which suffered pest attack had much higher rates of unfilled grain (see Appendix C). The major factor effecting crop loss to pests was variety choice and plant health (which is directly connected to soil fertility management). All of these factors, along with the crop establishment methods tested in this study like seeding and spacing determine rice yield levels. Experimentation which isolates these factors would further develop local rice cropping technique recommendations.

7.4 Water Control

The final aspect of producing good rice yields I will discuss is the amount of water available (i.e. rainfall, waterways and groundwater) and flooding conditions in the rice fields. It was mentioned earlier that the farmers are unwilling to create complex bunded systems to control water levels in the field due to labor constraints. As can be seen in Figure 20 there are varying levels of flooding in the fields that were tested. Those fields lying on the margins of the flooded land, not above the flood line or deep in the basin, had the highest yields. The alternating wet and dry conditions which these fields are subject to throughout the rainy season roughly mimic the recommended irrigation schedule under certain BMPs, and especially by the SRI principles. It is recommended that farmers who own land in this range should especially consider adding more land and labor into their rice cropping activities as they will likely have the highest returns. Farmers with land in the lowest and highest areas should consider creating earthworks to redirect and concentrate rainfall in their fields. If they are unwilling or unable to do this they should understand that better soil fertility management and variety choice may be necessary to increase their yields further.

As mentioned earlier the Belgian Development Cooperation is in the process of constructing a system of dykes and dams which effects the flooding pattern in the target villages (Belgian Development Cooperation 2013). Within a few years there will be improved control of flooding levels in the rice fields which could make 2 harvests in one year possible. The improved water control technology can complement the crop management principles the farmers learned in this study to further increase rice yields. It can potentially make relay cropping practices more sustainable as well. This will require high soil fertility inputs, as the land will be producing even more and stressing soil nutrient levels. Proper training on utilizing irrigation and dams for rice production will be vital in making the infrastructure project successful in improving local livelihoods. Community leaders or a local mason will need to learn how to maintain the equipment and structures being installed. The local PCV and Master Farmer should partner with the Belgian Development Cooperation to assist them in training activities and community organizing around this development project.

7.5 Rice Processing Labor Requirements

The labor requirements calculated for the adapted methods tested in this study (see Table 1, Table 2 and Appendix D) do not include the time it takes to process the rice for consumption. This is done daily by women in a mortar and pestle and requires about 15 minutes per kilogram. This was not included in the labor requirements since the action does not occur during the busy cropping season and does not affect the amount of time needed to actually produce the rice. It does however increase daily labor requirements for women. All of the farmers included in this study had already reintegrated rice processing into their daily workload. If farmers choose to continue to process rice by hand the yield increase caused by the new adaptations may further increase labor. This can be avoided by paying a percentage of harvest to have the rice mechanically milled in the nearby village of Katiotte. All of the improved cropping techniques tested exceeded the goal yield so this payment may be made while still bringing home enough rice to eliminate household spending.

This leads to the question of whether or not altering their rice cropping practices leads to on overall improvement in the farmers' quality of life. This study shows there will be a decrease in household spending while labor stays approximately the same. However, these are not the only two factors which contribute to quality of life. It may be the case that the labor time would be better spent growing a cash crop which will bring in more value than what is saved on rice purchases. The money may then be able to cover rice for consumption and some other necessary cost like school or medical fees. The main local cash crop is peanuts, which farmers inlvolved in this study report they are purposely reducing their production of in favor of rice. Nutritional, social and environmental effects of the new focus on rice production in these villages must also be explored to determine if the movement truly improves the livelihoods of the local populations.

CHAPTER 8

SUMMARY

Phase I of this study was conceived based on interactions I had with rice farmers while working as a field crop extension agent for Peace Corps in the Kaffrine Region of Senegal. Unique forces popularized rice cropping in just 4 villages in the area and this study was designed to learn more about the way local farmers produce rice and why. A survey of 32 rice farmers ascertained average yields, labor requirements, local techniques and farmer attitudes toward rice cropping. An overwhelming consensus among the target communities was the desire to reduce or eliminate spending on rice, which is about 18,8000CFA (about 40USD) per month per household. Those lucky enough to own land with soils appropriate for rice production felt it was important they use it for this end. This attitude was highly pervasive in 2012 when the survey was conducted even though rice farming had only been recently rekindled in the communities 5 years previous.

Farmer centered field research supported what was determined in the survey; local yields were around 1,040 kg/ha and cropping techniques required about 630 man hours per hectare per season. The method of rice cropping which produced these results was the same set of practices farmers in the Kaffrine region use to grow all grain crops. This was what they perceived to be the best way to grow rice, as the method is successful for other field crops. Animal traction machinery is used for soil preparation, seeding and between-row weeding. This usually resulted in plant spacing suboptimal for successful yields in rice. Misunderstanding of pest pressures and soil fertility management were also issues limiting production shown through the survey phase. Phase II introduced alternate crop management principles and educated farmers on proper soil fertility management.

Phase III of the study experimented with alterations to the current system to determine if self-sufficiency from rice expenditures was possible within the realities of farmers' labor availability, environmental limitations and willingness to adopt new techniques. The alterations to the current system which were tested were inspired by the principles of the agroecological System of Rice Intensification and were aimed at increasing yields, improving soil fertility and producing plants healthy enough to resist pest attack. Not all recommendations associated with the system were possible to implement in the context of the target villages. Instead adaptations were designed which took local sensibilities and common practices into account. This process was aided by Phase II of the study in which Peace Corps staff members and I were given training in SRI experimentation through an event coordinated by the USAID WAFSP and Cornell SRI-Rice. The main initiative of this phase of the study was sharing the knowledge gained at the training-of-trainers event to prepare motivated rice farmers identified in the survey stage to conduct field experimentation of the SRI adaptations. These farmers and the wider community learned about SRI principles and demonstration creation protocol at hands-on training events led by Peace Corps staff.

I and 10 farmers implemented the 3 SRI adaptations in the rainy season of 2013. The technique which most closely matched farmers' animal traction centered system was the most labor efficient and preferred by the farmers. This technique also on average produced just over the goal yield of 1,920kg/ha. The average plot size is 0.4 hectares from which, at the goal yield, a farmer would harvest 768kg of rice; the amount of rice the average farmer in the 4 target villages purchases in one year. If a farmer does not want to increase their labor inputs, or produce a surplus supply of rice to sell, a machine seeded and thinned method is recommended. Higher average yields were produced by a hand seeding method which is more labor intensive than the machine seeded adaptation. If a farmer hoped to produce a surplus and could input 23% more labor into the same 0.4ha plot a 28% increase in yield may be possible. The adoption of the variety NERICA-6 provided a 39% increase in yields if no other changes to crop management were made. It may be the case that this factor is the most important for farmers to reach self-sufficiency in rice expenditures.

CHAPTER 9

CONCLUSION

Rain-fed rice producers are most likely to invest in measures to upgrade their productivity when they involve minimal cash expense and show tangible benefits within a growing season. As subsistence producers, these farmers are less motivated by profit or direct monetary gains. Rather, they will be looking for non-monetary benefits that generate greater rice stocks for the household and decrease the amount of labor and other household resources devoted to rice production. These producers are likely to also respond to strong pressures of conformity to adopt prevailing practices among their peers or improved practices advocated by recognized leaders in their communities. (Wolfe et al. 2009)

The yields returned in any of the trials conducted in this study are not impressively high when considering that one hectare in the Senegal River Valley has shown the potential to produce 9 tons of rice. This supports the farmers' intuition to farm rice only for subsistence and not sale. The above quote approximates the attitudes and behaviors of the farmers I surveyed in the target villages for this study. The education and experimentation campaign provided the farmers with a costless adaptation to their current system that can eliminate their need to purchase rice. The changes to common current practices necessary to generate greater rice stocks for their households are minimal and may spread from farmer-to-farmer without further intervention. The Master Farm site nearby these villages can continue to promote the adaptation which necessitates 3 basic changes to the thinning process; (1) increase the space between plants to approximately 25cm, (2) leave only 1 seedling per hill and (3) thin between 8-13 DAP.

Adoption of the variety NERICA-6 has already begun in the target villages since its improved performance was obvious in the cropping season of 2013. Inputs of this seed can be provided by nearby Peace Corps volunteers as well as training in soil nutrient management.

As the population of Senegal increases so does the demand for imported rice. Field space and labor which were previously dedicated to peanut production are rapidly being reallocated as farmers lose faith in the benefits of producing the cash crop. The farmers in 4 villages in the rural community of Nganda which have access to the seasonal tributary the Bao Bolong have decided to dedicate their time to explore the potential of rice production. This study utilized an education campaign to facilitate farmer centered experimentation that proved household expenditures on rice could be eliminated without any increase in land, labor or money dedicated to rice production. Further experimentation on the main factors for producing good yields in the area is necessary to expand on local recommended BMPs. This study has proven that such future experimentation would be both beneficial and well received since the local fervor for the crop continues to grow. In an area where most rural extension education is focused on agroforestry, market vegetable production and millet cropping, this project showed local farmers that rice production has value and successfully fueled their dedication to the crop.

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APPENDIXES

Appendix A: Phase I Baseline Survey Conducted on 32 Farmers in the Target Villages (Contact Lorraine Perricone – Dazzo at LPerriconeDazzo@gmail.com for complete survey including coded answers)

Background Information

Name:
1)Village:
2)Male (2-1)   Female (2-2)
Age:
3) Married(3-1) or Single(3-2)
Number of Daughters:
Numbers of Sons:
4)Other members of the household:
4-a: # of Brothers   4-c: # of Aunts   4-e:# of daughter or sister in-laws   4-b:# of Sisters   4-d:#of Uncle

Assessment of Behavior and Attitudes Towards Rice Production

5) How many years have you cultivated rice?
6) Have you reduced or increased the amount of rice you produce in the past 5 years?
7) (7a)Do you think rice production should be increased in this area?
(7b) In Senegal in general?
(7c)Why or why not
8) Was there a time when rice was farmed on a larger scale then it is now here in this village?
9) (9a) Do you consider yourself knowledgeable about rice production?
(9b) Do most farmers here consider themselves knowledgeable?
(9c) If no, do any farmers here consider themselves knowledgeable?
10) (10a) How many meters squared of rice do you cultivate? __________m
(10b) Does this change from year to year?
11) (11a) Is the amount of rice you grow adequate for your household's consumption?
(11b)If not how many sacks do you purchase per month? _______CFA
(11c) What is the cost per sack (or per month total expenditure on rice)?______CFA
12) (12a)Do you sell your rice?
How much do you sell it for? _________CFA per sack
13) What is difficult about producing rice, for you?
14) (14a)Who does the labor for your rice production
How much are they paid? _________CFA
How many people total are available? ________people
15) Are you interested in increasing your rice production?
16) What is your average yield in one year? ________kg/ha -how many sacks produced________--average weight of a sack___________ -land area cultivated____________(Ask how many sacks they produce and using the meters squared dimensions they reported earlier and the average weight of the sacks determine kg/ha)
17) (17a) Is yield constant from year to year?
How much does it vary?
18) Would you be willing to try the SRI technique you saw demonstrated at the Master Farm of Fatou Willane this coming rainy season and compare it to your current system?
19) (19a)How many new agricultural techniques have you implemented in the last 10 or so years?___________
For Each Technique Reported Answer the Following and Code Afterwards:
-What was the technique? Where did you learn it? Have you used it since?
(19b) Have you been exposed to any other techniques you hope to try but have not yet?
(19c) What are they? (create a list and code as answers are compiled)

Assessing Current Practices and Knowledge

20) (20a) What percent of your rice is grown upland? _______%
(20b) What percent of your rice is flooded all season?________%
(20c) What percent of your land is cropped as a mixture of flooded and dryland? ________%

Seed

21) Where do you get your rice seed?
How many years have you stored your own seed ? _____year
22) When do you usually purchase/acquisition it?
23) How much do you spend on seed? _______CFA
24) How many kilograms do you purchase/request of seed? ________kg

(24a) Do you seed all of it?
25) (25a) What variety do you grow?
(25b)Which characteristics are desirable to you about this variety ?
(25c)Are there traits lacking in available varieties you would like? Describe them.
26) How do you store your rice seed?

Soil Preparation

27) What is the soil type in your rice field? (go to field and determine texture, create code later for soil types and a separate one for local names)
28) Rainfall amount____
29) How do you prepare the soil to be planted with rice?
30) Do you use a tractor?
(30-1) No (30-2) Animal (30-3) Manual
31) Do you level the soil? (31-1) Yes (31-2)No
32) Who does the work of ploughing and leveling the field?
33) How much time does ploughing, preparing, and leveling the soil take in your rice field?________________man hours (calculate this based on the m^2 of their field) ________man hours per hectare
34) Describe the tools.
(34a) Is there a better tool available? Yes (34-1) No (34-2) (34b) :If answered yes, why don't you use it?

Seeding

35) (35a):What percent of your rice fields are direct seeded? _____%
(35c):What percentage of your fields are broadcast?_________%
(35b): What percent of your fields are transplanted? _______%
(35c):When/how do you seed?

If transplanted:
36) How long do you keep seedlings in the nursery? ______weeks
37) How much seed do you require to create your nursery (kg)? ________kg
38a) How big is your nursery? _________m^2 (38b): How big is the field you can plant with this nursery? ______m^2
39a) How many seedlings do you transplant per hill? _________per hill
(39b): What is between row spacing of your transplanted rice plants? __________cm between rows
(39c): What is the in row spacing of your transplanted rice seedlings?___________cm within rows
40) Who does the work of nursery creation and transplanting the field?
41) How much time does nursery creating and transplanting take in your rice field ________________man hours (calculate this based on the m^2 of their field)________man hours per hectare

If seeded in rows:
42) Do seed in row by hand or by machine?
43) What number disc do you use?
44) What is between row spacing at which you thin to? __________cm between rows (44c): What is the in row spacing at which you thin to?___________cm within rows
45) How many plants to you thin toper hill?_______plants
46) If seeded by hand, how many seeds per pocket?___________seeds (46b):How many plants do you thin to per hill if in-row seeded by hand? _______plants
47) How much seed (kg) are required to direct seed or hand seed your rice plot? ________kg(calculate kg/seed/ha)
48) Who does the work of seeding in-row your rice field?
49) How much time does seeding in-row take in your rice field ________________man hours ________man hours per hectare

If Broadcast:
50) How much seed (kg) are required to direct seed or hand seed your rice plot?________kg (calculate kg/seed/ha based on plot size)
51) Who does the work of broadcast seeding your rice field?
52) How much time does broadcast seeding in your rice field ____________man hours ____________man hours per hectare

Field Management

Weeding
53a) How do you weed?
53b) Is there a better tool available?
53c)Why don't you use this improved tool:
54a)How many times do you weed?
54b) When?
55) Which weeds in particular do you have problems with in your rice field?
56) Who does the work of weeding your rice field?
57) How much time does weeding take in your rice field ________________man hours ______________man hours per hectare

Nutrient Management

58a) Do you incorporate organic matter into your soil? (58-1) Yes (58-2) No
58b) What organic matter do you incorporate into your soil?
58c)Is your organic matter incorporated or laid on top?
58d) When do you bring the organic matter?

59) Who does the work of bring organic matter to your rice field?

60) How much time does bringing organic matter to your rice field ________________man hours _______________man hours per hectare

61a) Do you use chemical fertilizer? (61a-1) Yes (61a-2) No

61b) What kind?

61b-1) NPK (61b-1*)How many kg in your field space?______kg (recalculate for Kg/hectare)

61b-2) Urea (61b-2*) How many kg in your field space?_______kg (recalculate Kg/hectare)

61c) When do you apply fertilizers?

61d) How do you apply?

62) What do you use the crop residues for?

Pest Management

63a) Do you have problems with insects? (63-1)Yes (63-2) No

63b) Which? What do you do to control?

63c) How do you apply poison?

63d)For each pest listed above which you use poison to control, what kind of poison do you use?

How much in your reported field space? ________Kg/bottles etc

63e)For each insect listed above, for how many of the past 5 years has it been a problem?

64a) Do you have problem with disease or fungus?

64b) Which disease/fungus or describe how it affects the plant?

64c) How do you control it?

64d)For each disease or fungus listed above which you use poison to control, what kind of poison do you use?

64e) How much in your reported field space? ________Kg/bottles etc

64f)For each disease or fungus listed above, for how many of the past 5 years has it been a problem?

65a) Do you have problems with birds?

65b) Mice

65c) What is your current solution to bird or mice problems?

If Poison what kind? _________

How much in your reported field size?_________kg/bottles etc

65d)For mice and birds, for how many of the past 5 years has it been a problem?

66a) Are there any other pest problems?

66b)Describe them and your current solution.

67) Who does the work of pest control to your rice field?

68) How much time does pest control take on the field of the size you reported ________________man hours

Irrigation and Harvest

69) Can you irrigate?

70) Is your crop only rain fed?

71) By which date are your flooded fields ready to be planted in the past 5 years?

72) How do you harvest?

72) Who does the work of harvest in your rice field?

73) How much time does harvesting take on the field of the size you reported ________________man hours _________man hours per hectare

74) How do you dry the grain?

74a) How do you thresh the grain?

74b) Where do you thresh the grain?

75) Who does the work of threshing your rice?

76) How much time does threshing take to take care of the amount of rice you grow the field of the size you reported ________man hours

77) How do you process the rice for consumption?

78) Who does the work of processing the rice?

79) How much time does processing the amount of rice you grow the field of the size you reported ________________man hours

Appendix B: Field Experimentation Form
Adapted by Lorraine Perricone – Dazzo from a form by Erika Styger

Data collection **sheet SRI**

Projet

Region | Technician | *Admin unit:*

Village: | Name

Farmer Name	Farmer *Number:*	**Irrigation** scheme name	
		SRI	Control
Dimension **Plot**			
(m x m)			
Plot **Preparation**			
Application Organic Matter			
	Date		
	Type		
	Quality		
	Quantity		
	Price		
	Transportation price		
	Spreading (Manhour)		
Base fertilizer application			
	Type		
	Date		
	Quantity/plot		
	Price		

		Transportation cost	
	Spreading (Manhour)		
Plot preparation			
	Type		
	Date		
		Man hours	
	Costs		
Plot preparation			
	Type		
	Date		
		Man hours	
	Costs		
Plot preparation			
	Type		
	Date		
		Man hours	
	Costs		
Plot preparation			
	Type		
	Date		
	Man hours		
	Costs		
Nursery			

Nursery **establishment**			
	Dimension (m x m)		
	Establishment costs (man hours/price)		
	Added materials (sand, compost)		
	Costs of added materials		
	Other:		
Seeding **of Nursery**			
	Date of Seed soaking		
	Hours of seed soaking		
	Date seeding		
	Quantity of seed		
	Variety of rice		
	Quality of seed (R1 etc)		
	Origin of seed		
	Man hours for seeding		
	Emergence (day after seeding)		
	Vigor (weak - medium - strong)		
Nursery **maintenance**			
	Frequency of watering		
	man hours		

	for watering/maintenance		
	Damage: Yes (% surface damaged) / No		
	Reason for damage		
	Others		
Transplanting			
Plant removal from nursery: date			
	Man hours		
Transportation: Date			
	Man hours		
Transplanting: date			
	Age of plants (days)		
	Number of leaves		
	Number of plants/hill		
	Spacing between plants		
	Man hours		
	Costs		
Crop Management			
Fertilizer			

	Urea 1 ; Date		
	Quantity/plot		
	Costs of fertilizer		
	Transportation costs		
	Spreading (man hours)		
	Urea 2 ; Date		
	Quantity/plot		
	Costs of fertilizer		
	Transportation costs		
	Spreading (man hours)		
	Other ; Date		
	Quantity/plot		
	Costs of fertilizer		
	Transportation costs		
	Spreading (man hours)		
Weeding			
1	Date		
	Method		
	Man hours		
2	Date		
	Method		
	Man hours		
3	Date		
	Method		
	Man hours		
4	Date		
	Method		
	Man hours		
5	Date		
	Method		
	Man hours		

Irrigation			
1	Date		
	Time in minutes		
2	Date		
	Time in minutes		
3	Date		
	Time in minutes		
4	Date		
	Time in minutes		
5	Date		
	Time in minutes		
6	Date		
	Time in minutes		
7	Date		
	Time in minutes		
8	Date		
	Time in minutes		
9	Date		
	Time in minutes		
10	Date		
	Time in minutes		
11	Date		
	Time in minutes		
12	Date		

	Time in minutes		
13	Date		
	Time in minutes		
14	Date		
	Time in minutes		
15	Date		
	Time in minutes		
Pest Attack			
	Date		
	Pest Type		
	Damaga		
	Control measure		
		Date	Date
Phenology			
1	Germination		
2	Appearance		
3	Tillering		
4	Beginning of booting		
5	Booting		
6	Beginning of flowering		
9	Flowering (100%)		

10	Beginning grain filling		
11	Milk stage		
12	Stade Pateux		
13	Beginning panicle inclination		
14	Inclination of panicles (100%)		
15	Maturation		

Appendix C: Harvest Data Collection Sheet

By Erika Styger

Harvest SRI

Village:
Farmer Name:

Date:
Variety:

SRI Plot

Plant	No tillers	No panicles	Plant height (cm)	Root length (cm)
1				X
2				
3				X
4				
5				X
6				
7				X
8				
9				X
10				

Harvest square 1m2

Square	No plants	Weight (g)	Humidity %
S1			
S2			
S3			
S4			
S5			

Panicle analysis

Panicle	Length (mm)	No grains	No empty grains
P1			
P2			
P3			
P4			
P5			

Control Plot

Plant	No tillers	No panicles	Plant height (cm)	Root length (cm)
1				X
2				
3				X
4				
5				X
6				
7				X
8				
9				X
10				

Square	No plants	Weight (g)	Humidity %
S1			
S2			
S3			
S4			
S5			

Panicle	Length (mm)	No grains	No empty grains
P1			
P2			
P3			
P4			
P5			

Appendix D: Breakdown of labor requirements for specific field actions in the target villages

By Lorraine Perricone - Dazzo

Source	Action	Man hours per season per hectare
Information gathered during implementation of test and control plots in Phase III	Hand weed (entire 3x)	90
	Weed by machine (3x)	15
	Thin	5
	Hand weed within-row after machine weeding(3x)	90
	Seed by machine	12.5
	Seed by Hand at 25cmx25cm	75
	Nursery Management + Transplanting	85
	Soil Prep and Organic Matter Application	40
Information calculated from farmers' reports in Phase I	Harvest	332
	Thresh	20
	Winnow	120
	Process for Consumption	15 mins per kilogram

Appendix E: Detailed results of plant analysis from Phase III

Average per m^2	Babocar Gueye		Thiendou Willane		Keba Cisse		Mary Diop		Mat Mbaye		Mordu Seck	
Plot	**C**	**SRI**	**C**	**SRI**	**C***	**SRI**	**C1**	**SRI**	**C1***	**SRI**	**C1**	**SRI**
Plant Analysis												
# Tillers	6	13	15	12	5	13	18	11	8	13	9	9
# Panicles	5	12	12	11	3	10	12	17	6	10	8	8
Height (cm)	94	122	98	88	68	119	96	112	79	93	116	123
# Plants	22	8	7	10	27	14	13	10	18	13	4.2	10
Harvest												
Weight (g)	164	249	181	153	44	244	154	262	176	345	116	261
Panicle Analysis												
Length (mm)	258	283	259	262	183	251	258	263	231	231	295	269
# of Grains	149	189	183	143	186	147	142	177	174	189	221	212
# of Empty Grain	12	7	15	19	86	30	42	3.6	24.2	10	11	9

*Seeded with the variety Sayel-108, all other treatments seeded with variety NERICA 6