EXAMINATION OF IMPROVED WEEDING TECHNOLOGIES WITH SMALLHOLDER RICE FARMERS IN SOUTHERN BENIN, WEST AFRICA

A Project Paper

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by

Anne-Marie Mitchell

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ABSTRACT

Advancements of simple technologies such as weeders can aid in reducing labor for smallholder rice (*Oryza sativa*) farmers in sub-Saharan Africa. This paper, through farmer experimentation, will examine the use of an ecologically adapted and locally made weeding instrument for the southeastern region of Benin. With the assistance of the Union of Rice Farmers of the Oueme Plateau (URIZOP), the Collaborative Council of Rice Farmers in Benin (CCR-B), and Farm Integrated Agricultural Solidarity (SAIN), 30 rice farmers from the Oueme, Plateau, Zou, and Collines regions were selected to experiment weeding with a mechanical hand-push weeder and were subsequently surveyed to determine the weeder's advantages and disadvantages. Farm trials were conducted to determine the efficacy of the two weeding methods: by hand or with the mechanical weeder. Results point to an 80% reduction in weeding time and a positive response from farmers located in plateau and upland areas.

BIOGRAPHICAL SKETCH

Anne-Marie Mitchell graduated from University of California, Santa Cruz in 2012 double majoring in politics and philosophy. Both an exploration in agriculture and a curiosity with Africa led her to a dual masters program with Cornell University and the United States Peace Corps. From 2014-2016, she served as an agriculture volunteer in southeastern Benin in West Africa. She will to return to Cornell in the fall of 2016 for a Masters in Business Administration with intentions of working for the food and beverage industry.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BMP	Best Management Practice
CCR-B	Collaborative Council of Rice Farmers in Benin
ONASA	National Office in Support of Food Security
SAIN	Integrated Agricultural Solidarity
SRI	System of Rice Intensification
SSA	Sub-Saharan Africa
URIZOP	Union of Rice Farmers of the Oueme Plateau
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 General Background

Benin is located on the coast of West Africa bordered by Nigeria to the West and Togo to the East (Figure 1). Lying between the Equator and the Tropic of Cancer, Benin ranges from 6°30' N to 12°30' N longitudinally and 1° E to 3°40' E latitudinally. Its total area is 112,622 km^2 (43,484 sq mi) of which roughly 41% are forested areas (UN, 2010). It is one of the smallest countries in West Africa.

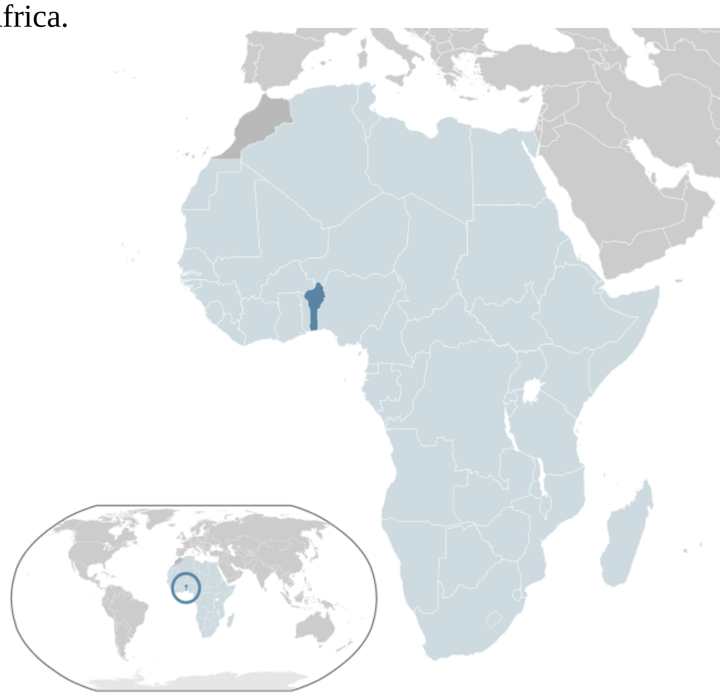

Figure 1. Location of Benin. Source: Wikipedia, 2009

There is very little variation in Benin's topography, with average altitude of 200 m (656 ft) in elevation. Benin's climate is generally hot and humid with annual rainfall decreasing from north to south, ranging from an average of 1,360 mm along the coast to 850mm in the arid north. Benin has a population estimated at roughly 9.1 million growing at an annual rate of 2.7% (World Bank, 2012; UN, 2011) that tends to live more in the southern and urbanized regions than in the northern, rural regions. Uniquely, Benin has approximately 42 socio-linguistic groups the most prominent of which is Fon, Nagot-Yoruba, and Bariba. Agriculture and regional trade are the predominant drivers of the Beninese economy.

1.2 Agriculture

As with many African countries, Benin's agricultural resources are the main contributor to its national economy accounting for roughly 40% of the country's GDP. Agriculture production in this country is mainly characterized by rain-fed subsistence farming with common crops including cereals (maize, sorghum, rice), legumes (beans, peanuts), and tubers (yams, cassava) (Achigan-Dako et al., 2009). More profitable crops include cotton, cashews, and palm oil. Of all Benin's exports, 70-80% consist of agricultural products that are sent to countries including China, India, and Nigeria.

1.2.1 Major crops

Among cereals, maize is a major crop that is grown throughout Benin. Its rotation differs from region to region depending on consumption patterns and comparative advantages of other agricultural products, however, moving southwards, the production of maize increases (van den Akker, 2007). Sorghum, the second major cereal crop, is often grown in the north in areas that are less favorable for agricultural production. Rice falls third as the most grown cereal crop in the country (USDA, 2013). Tubers have the highest importance in terms of production quantity and value, particularly cassava, which is grown from the center to the south of the country (FAOStat, 2012). Yam, another common tuber, is grown in the north and center of Benin. Beans and peanuts represent the most important legumes grown, and are cropped in equal measure throughout the country and help to improve soil fertility and nutritional quality.

1.2.2 Challenges

Transport, environmental changes, land limitations, and resource limitations pose challenges to many Beninese farmers. Transportation costs and poor road maintenance often create a significant challenge to bring agricultural produce from farms to desirable markets. Environmental changes can further impact this difficulty, as demonstrated by the heavy flooding caused by more erratic and extreme climate events in 2010 that affected much of the country causing displacement, soil erosion, and crop loss. Rising temperatures and declining rainfall in other areas, especially in the North may also alter the patterns of the growing seasons in addition to furthering spatial extension and intensification of soil degradation. Because lowlands, sinks, and valleys are preferred locations for agriculture, they can also experience overuse and imbalance of soil nutrients. Limited access to resources and inputs also affect farmers, resulting in low yields and lower quality products. These resources/inputs could be as simple as an understanding of BMPs, to more costly equipment or inputs such as weeders, or availability in the market.

While Beninese rice farmers are increasingly using BMPs, due in large part to the efforts of promoting the System of Rice Intensification (SRI), one of the biggest drawbacks for farmers is the sheer amount of time it takes to transplant and weed rice fields. Currently, there exists a knowledge gap concerning the utility of weeders, as noted by a study conducted in Benin by Gongotochame et al. (2014) and researchers of AfricaRice (formerly the West Africa Rice Development Association or WARDA). This study, which had farmers test an array of weeders over a brief time period, also suggests that the adoption and use of weeders would likely be greater if farmers were given the opportunity to use weeders for an entire season. Intentional introduction of weeders can aid in addressing both the perceived drawback of BMPs and adoption limitations of improved technologies.

1.3 Hypothesis

The purpose of this study is twofold: 1. To survey the implementation of weeders with smallholder farmers in southeastern Benin and 2. To analyze the effectiveness of a mechanical weeder in controlled field tests. It is assumed that the mechanical weeder, depending on the soil type, will prove to be more efficient than more rudimentary weeding methods (by hand or with a hoe) therefore decreasing the time it takes to weed. Farmers applying the weeder in their respective fields will likely experience similar results. It is likely that their experiences using the weeder will be largely positive, should the weeder be well adapted to his or her soil condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Rice imports and production

Rice is the leading provider of calories in West Africa and is the second largest source of food energy in sub-Saharan Africa (SSA) (Seck et al., 2010). Total rice consumption in Africa was estimated at about 21.19Mt in 2010, and this number is steadily growing at a high rate in SSA (Africa Rice Center, 2012). In Benin, rice consumption has drastically increased, growing at an annual rate of 47% between 2001 and 2005, compared to the annual average of 6.55% for West Africa (Seck et al., 2013). Moreover, reports from the United States Department of Agriculture (USDA) of milled rice imports to Benin shot up from 160,000 MT in 2009 to 350,000 MT in 2012, an increase of 118%, and have remained high since (Figure 2) (USDA, 2014). These increases are attributed to urbanization, population growth, income, and other factors such as ease of storage and preparation when compared to other foods (Africa Rice Center, 2011; Calpe, 2006; USAID, 2009).

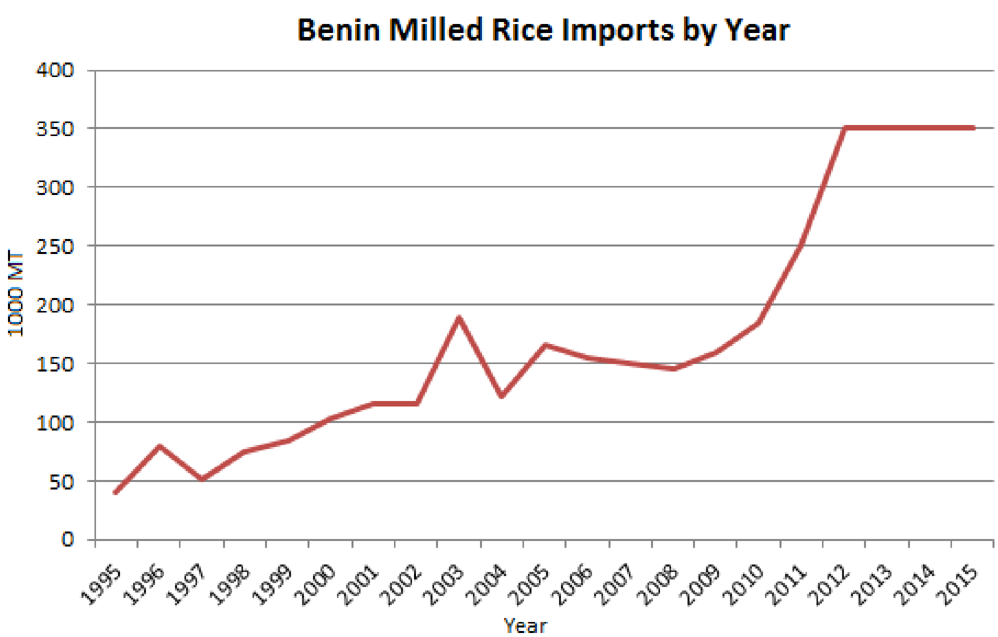

Figure 2. Benin milled rice imports by year. Modified by author from Indexmundi, 2015

There is increasingly more rice being farmed as well (Seck et al., 2013). Total production of rice for Benin for MY 2012/2013 was 127,757 tons, and is generally increasing (Figure 3) (USDA, 2013). Reasons for this include: research advancements by the Africa Rice Center, its partners, policy measures implemented by governments (Seck et al., 2012; Seck et al., 2013), the use of improved seed and cropping practices, the dissemination of technical information and knowledge, capacity development, and support for the development of rice markets and value chains (Naseem et al., 2012). However, further growth is hindered by the lack of or limited access to infrastructure, mechanization, rural credit, fertilizer, insecticides, seeds, soil fertility methods, and yields (Rondon, 2013). Extreme climatic conditions, particularly rainfall patterns, also affect the improvement of rice production. Furthermore, and to the detriment of locally produced rice, 43% of the Beninese populations in both urban and rural areas prefer imported, perfume rice varieties from Asiatic countries (USDA, 2013). Despite improvements, urban consumers in West Africa still regard domestic rice to be of poor quality compared to imported varieties because of factors such as damaged and yellow grains, incomplete milling, discoloration, impurities, consistency after cooking, and/or undesirable odor and taste (AfricaRice Center, 2011; Adetonah et al., 2010). The price for imported rice is between FCFA 532/kg and FCFA 612/kg (USD $1.04-$1.20) whereas the price for local rice is FCFA 393/kg (USD $0.77) (Rondon, 2013).

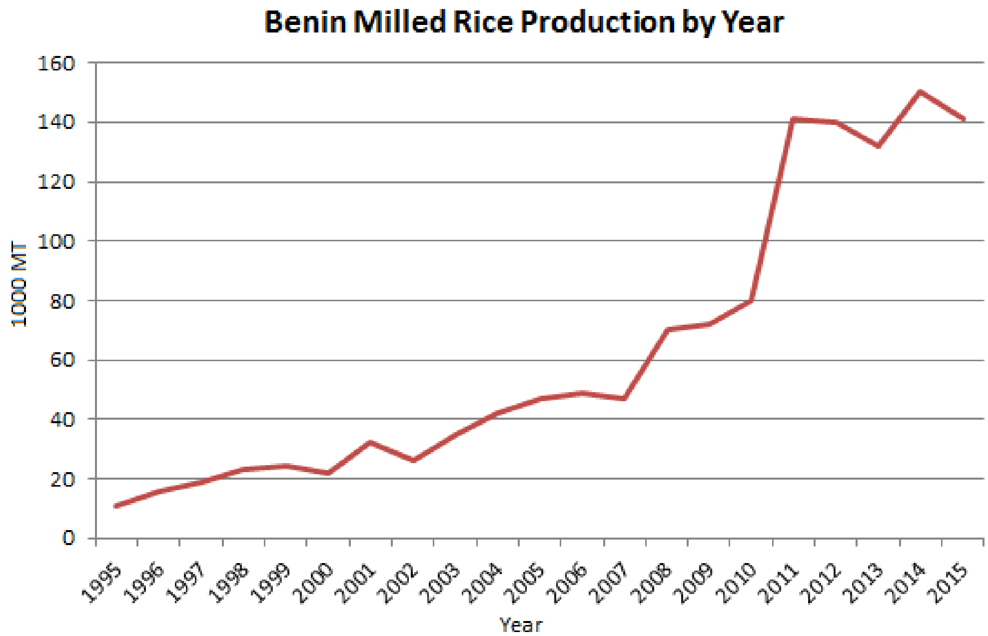

Figure 3. Benin milled rice production by year. Modified by author from Indexmundi, 2015

Since 2008, the government of Benin has been actively working to improve the agricultural sector through development of value chains. Maize and rice are two staple crops that have received increased attention in this initiative. The government's goal, through its Strategic Plan for Agricultural Diversification and Productivity, is to increase total grain production and to look for a means of developing official rice exports, which they aim to do by 2018 (USDA, 2013). Additional provisions to the agricultural sector will hopefully see this goal to fruition; however, the government position is often inconsistent with Benin's current realities afflicting the rice sector.

There are a number of contributors to rice production and processing in Benin, including other governments, non-governmental organizations, and international organizations, that may aid in the development of Benin's rice sector, however. The National Office in Support of Food Security (ONASA), for example, assists in marketing by buying and storing rice between harvests, which helps to control market supplies and price surges. ONASA began operating two additional rice mills in 2011 to aide in this process. While increased milling facilities aid in the rice sector, Benin faces difficulty branding the appeal of locally grown rice, particularly in the north where 75% of rice grown leaves the country via traders from Niger and Nigeria (Rondon, 2013).

Rice is grown throughout Benin with major rice provinces in the Oueme/Plateau, Borgou/Alibori, Zou/Collines and Mono/Coffo (Figure 4) (Rondon, 2013). Average rice yields are often 1-2 ton/ha paddy, but are increasing with the implementation of best management practices (BMPs) and improved seed varieties.

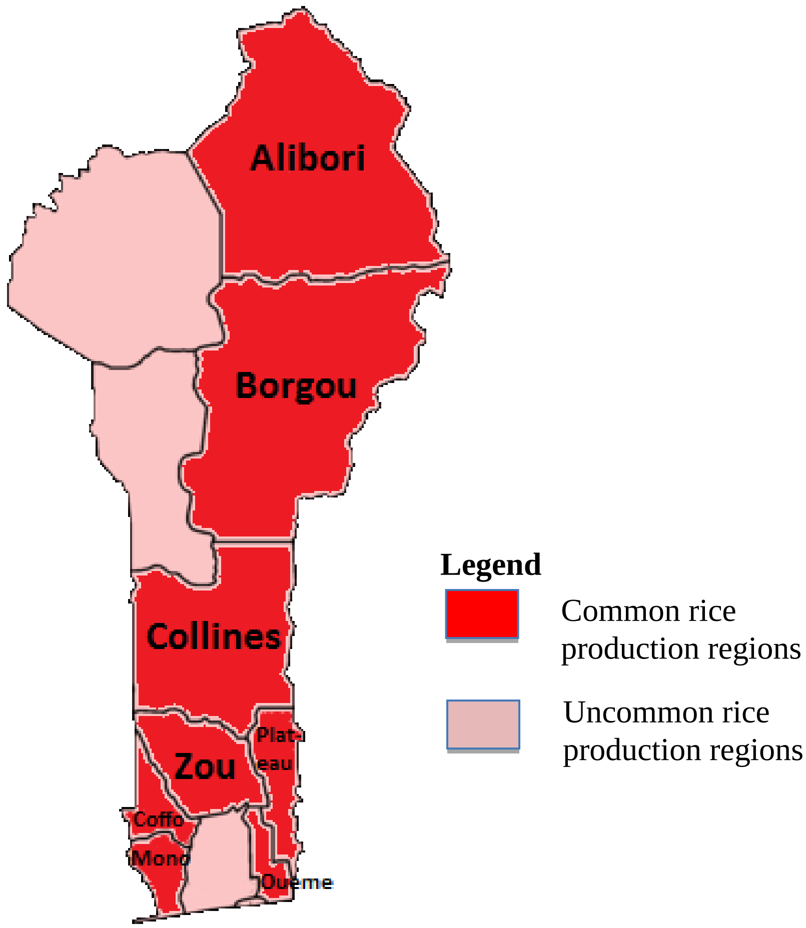

Figure 4. Rice production regions in Benin. Modified by author from Wikipedia, 2009

2.2 Rice Management Systems

While rice production is prominent in the arid north of Benin, southern lowland areas, including rain-fed and irrigated flood plains and valley bottoms, are the most promising for intensive rice growing systems and multiple crops per year account for roughly 30% of rice cultivation areas in West and Central Africa (Somado et al., 2008). Inland valley bottoms are estimated to cover roughly 30 million hectares in West Africa (Thenkabail et al., 1995), however, only 10% has been used for agricultural production (Becker & Johnson, 2001). Gruber et al. (2009) estimates that 194,900 ha of flood plains and inland valleys in Benin are still exploitable for agricultural production.

Singbo and Lansink (2009) describe lowland cultivation in Benin as comprising of three major farming systems: (1) integrated rice-vegetable farming systems, where rice is produced during the rainy season while vegetables are cultivated in the dry season; (2) rice farming systems, where only rice is cultivated in the rainy season (May to November); and (3) vegetable farming systems, when only vegetables are produced in the dry season (December to April). Constraints to lowland rice systems include weeds, drought, soil infertility, and blast disease; additionally, lowland areas also experience flooding, iron toxicity, rice yellow mottle virus and African rice gall midge (Somado et al., 2008). In describing problems of commercialization in rice production, farmers and experts also mention that many individuals do not know the necessary processing techniques, thus resulting in a lower quality product (Gruber et al, 2007).

2.3 Lowland Weeding

Rice grown in lowland areas across West Africa vary by ecological conditions, from flooded to non-flooded environments depending on the slope of the land, geographic position, or height of the water table (Defoer et al., 2004). Weeds present a major constraint to rice production (Balasubramanian et al., 2007; Nhamo et al., 2014; Seck et al., 2012), reducing yields from 28 up to 54% in transplanted rice and from 28 to 89% in direct-seeded rice (Akobundu, 1980; Becker et al., 2003; Johnson et al., 2004; Rodenburg & Johnson, 2009). Globally, crop yield loss from weeds account for 10% of yield loss (Fletcher, 1983).

For farmers, fieldwork, particularly weeding, often requires either time or capital (Gianessi, 2009; Rodenburg & Johnson, 2009). Time or resources used for weeding may consequently affect farmers' direct or indirect household economic activities (N'cho et al., 2014). Labor for weed control when producing rice has been estimated to account for one-third to one-half of overall labor, averaging 30-40 days of labor per hectare and 8-10 hours per day (Hobbs & Bellinder, 2004). Encouragingly, studies conducted on upland rice crops in SSA by Ogwuike et al. (2014) found that weeding more than once increases weeding labor efficiency by about 37% and rice productivity by more than 27%. Further, a study by Rodenburg et al. (2015) demonstrates that weeding time is significantly shorter with a rotary weeder compared to hand weeding. It also eases the drudgery of weeding.

Limited availability of affordable and alternative weeding practices continues to burden smallholder farmers (Rodenburg & Johnson, 2009) who rely mainly on manual (hand), hoe weeding, or, to a lesser extent, herbicide application (Adesina et al., 1994). Hand or hoe weeding is often time-consuming, labor intensive, and can come at a high cost to farmers (Melander & Rasmussen, 2000; Ramahi & Fathallah, 2006; Remesan et al., 2007). In one study by Remesan et al. (2007), the cost of weeding was reduced by between 5 to 7 times using a mechanical weeder compared to hand weeding. An added benefit of a mechanical weeder is the aeration of soil during weeding (Babar & Velayutham, 2012).

While there has been some effort in the distribution of the cono-weeder in SSA, a weeder best used in irrigated lowlands, no other mechanical weeders apart from traditional hoes are commonly used or available in sub-Saharan countries (Gongotochame et al., 2014). This is in part due to the limited understanding of a mechanical weeder's utility (Gongotochame et al., 2014), but is also a result of weighing the cost for these tools in relation to other field necessities such as netting (to protect rice fields from predators, such as birds), labor costs, and local availability of weeders. Instruction and implementation of appropriate weeding instruments can aid smallholder rice farmers in improving their yields, lessening their time spent working in the fields and improving the economic efficiency and overall productivity of agricultural systems in West Africa (Singbo & Lansink, 2009).

2.4 Weeders Used in Rice Production

2.4.1 Common weeders

The weeders listed below are those that are often employed by research institutions, such as AfricaRice, and large agricultural companies, such as Songhai Center located in Benin. While they can be custom made by local welders/workshops or made available by larger organizations to smallholder farmers, they are often costly. The predominant method of weeding for all farmers is often hand weeding with a small instrument such as a hoe.

a) Ring hoe weeder

The ring-how weeder (Figure 5) is a manual push weeder that can be either pushed forward or pulled backward, scraping the soil surface (RiceHub, 2015). The rotary frame consists of a round plate with small spikes in front of it to effectively cut the weeds at the ground level. This type of weeder is often used in irrigated, lowland, or upland rice production systems and was the preferred type of weeder in non-ponded conditions in a study conducted by Gongotochame et al. (2014) with rice farmers in southern Benin.

Figure 5. Ring hoe weeder. Source: RiceHub, 2015

b) Straight-spike weeder

The straight-spike weeder (Figure 6), an Asian model introduced in a few countries in SSA such as Burkina Faso (Gongotchame et al., 2014) is a manual push-and-pull weeder that uses two cylindrical wheels and a star-shaped spike and sharp blade to cut and uproot weeds (RiceHub, 2015). Its black metallic keel aids in guidance. Like the ring-hoe weeder, the straight spike weeder can be used in irrigated, lowland, and upland rice production systems. In studies by Rodenburg et al. (2015), the straight-spike weeder reduced weeding time by 32 to 49%.

Figure 6. Straight-spike weeder. Source: RiceHub, 2015

c) Cono-weeder

The cono-weeder (Figure 7) is a manual push-and-pull weeder that uses two conical wheels with flat and sharp blades that sit behind a front tilted metallic float to act as a direction guide (RiceHub, 2015). This floating mechanism makes it ideal for irrigated or lowland systems. Studies by Remesan et al. (2007) found that cono-weeders perform best during initial stages of weed growth.

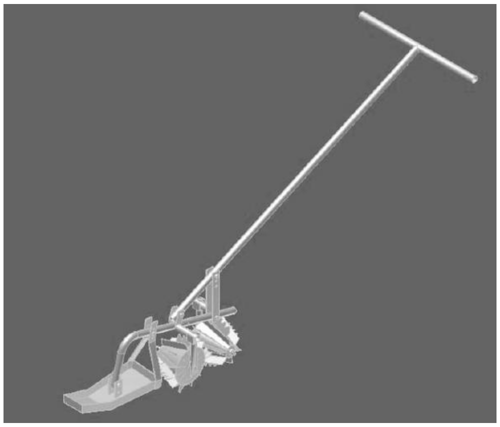

Figure 7. Cono-weeder Source: RiceHub, 2015

d) Wheel hoe weeder

The weeder used for this experiment is an Indian-inspired wheel hoe model imported from Mali (Figure 8). It is constructed with a 25mm round tube frame, a 30x5mm flat iron roulette, and a 25x3mm forged iron dent. A simple design, this weeder only weighs 11 pounds and has a 10 year life expectancy. Based on initial testing, it has the capacity to cover 0.25 ha/day. Originally found in Mali, it costs approximately 25,000 FCFA ($50 USD). However, because it is not yet streamlined in Benin, costs 40,000 FCFA ($80) when made locally. Unlike cono-weeders, one of the only available weeders for purchase in Benin, this weeder has the advantage of simplicity and lower cost. It is also able to cut and uproot weeds, like the popular cono-weeder, and is more advanced than the ring-hoe weeder. This weeder was designed to be used in dryland conditions.

Figure 8. Imported wheel hoe weeder used in study. Source: Société Coopérative Artisanale des Forgerons à l'Office du Niger, Mali (SOCAFON), 2016

2.5 Soils

Benin's soils are mostly tropical ferruginous soils (soils that contain iron oxides or rust) known as lixisols, which is reflective of the geologic conditions, grassland vegetation, and savannah climate found throughout the country (Earthwise, 2015). Because of the soil's high-clay composition it is prone to crusting and compaction (Saidou et al., 2003, 2004). These soils often have low fertility, so improving soil fertility is one of the main drivers to expand the use of this land for farming purposes.

In the areas surveyed under farmer experimentation in the Oueme, Plateau, Zou and Collines regions, four types of soils are present: gleysols (GL), nitisols (NT), arenosols (AR), and vertisols (VR) (Figure 9). Gleysols are characterized as wetland soils that are saturated for long periods of time and often develop "gleyic" color patterns of reddish, brownish, or yellowish layers. These soils are often found in low landscapes with shallow groundwater. In order to best utilize gleysols, a drainage system must be in place. Drained gleysols can be best used for arable cropping, livestock farming, and horticulture. Tree crops can also be planted in gleysols, and if planted on ridges can be intercropped with rice. Wetland rice has also been cultivated on gleyic soils if the climate is favorable (IUSS, 2006).

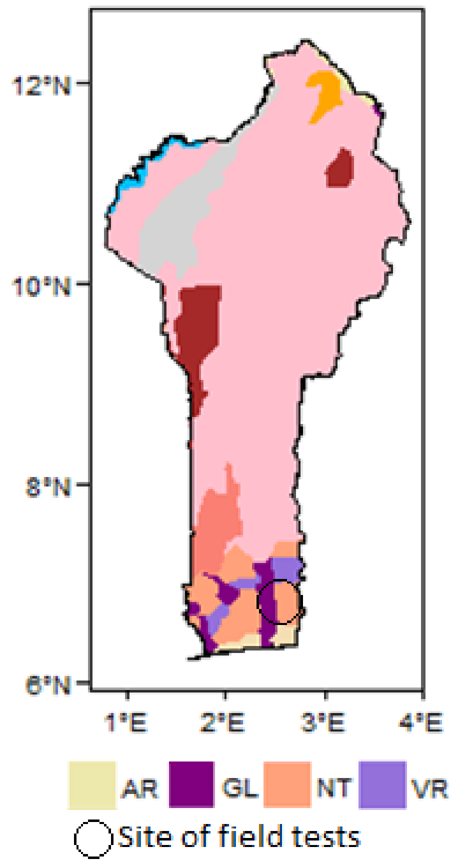

Figure 9. Soils map of Benin. Source: Modified by author from Earthwise, 2015

Nitisols are red, deep, well-drained, tropical soils. Their subsurface horizons typically break down to 30 percent clay and blocky structured elements. Weathering occurs quickly in these soils and is common to tropical rainforests or savannah vegetation. More than half of all nitisols are found in tropical Africa. They are known as one of the most productive soils in the humid tropics. The structure and subsoil layers allow for deep rooting and are more resistant to erosion. Drainage and water holding properties in addition to its high content of weathered materials are makes this soil particularly workable. Plantation crops are often planted in this soil type (IUSS, 2006).

Arenosols are characterized as a sandy soil whose landforms tend to vary from dunes, beach ridges, and sandy plains to plateaus. Vegetative landscapes can also vary from desert to grassy fields to forest. These soils are one of the most extensive reference soil groups in the world. Their variable nature also makes them variable for agricultural purposes. Their coarse texture is common, as is their capacity to store water and nutrients yet they can also offer strong capability for rooting (IUSS, 2006).

Vertisols are known for heavy clay content. In periods of drought, they form deep, wide cracks on the ground surface downward. By definition, they are known for their high rate of material turnover through weathering mechanics of swelling and shrinking clay affected by climatic shifts. Vertisols have good potential for use in agriculture but require continued management of water and fertility for continued yields. Cotton is commonly grown on vertisols, as it is largely unaffected by severe soil cracking. Waterlogging can also limit the growing periods of crops and the ability to infiltrate water (IUSS, 2006).

2.6 Climate

Benin's tropical climate is heavily influenced by the West African Monsoon (McSweeney et al., 2012). Avera rainfall (Figure 10) is determined by the movement of the tropical rain belt, which migrates between north and south positions throughout the year (McSweeney et al., 2012). Southern Benin has two rainy seasons: March to July and September to November. Temperature variations are most dramatic in the north, while further south temperatures reach up to 27-32°C in the warmest season and 22-25°C in the coolest season (McSweeney et al., 2012). Average annual temperatures have increased by 0.24°C each decade since 1960 and the average number of 'hot days' per year has increased by 39 between 1960 and 2003 while the number of 'cold days' have decreased (McSweeney et al., 2012). For the whole of Benin, the mean annual temperature in 2015 was 27°C (NCEA, 2015). Total annual precipitation in 2015 was 1150mm (NCEA, 2015). In addition to rising temperatures, Benin also faces the potential intensification of sea level rise.

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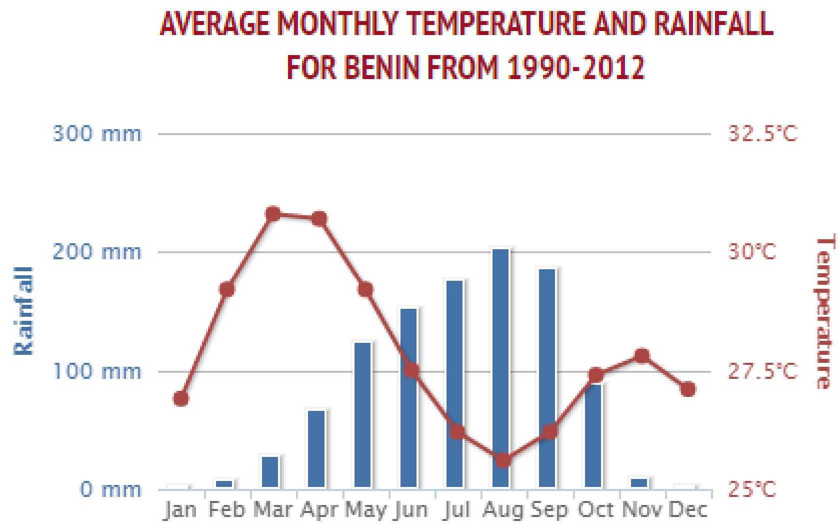

Figure 10. Average monthly temperature and rainfall (1990-2012). Source: World Bank Group, 2016

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the Area Studied

3.1.1. Location

Field tests were conducted at Farm Integrated Agriculture Solidarity (SAIN) in Kakanitchoé, located in the Oueme region of Benin at approximately a longitude of 6°45'51.1''N and latitude of 2°30'41.8''E (Figure 11) (Google Maps, 2016).

Figure 11. Location of field tests. Modified by author from Google Maps, 2016

Soil conditions at this location are most closely matched to the nitisol soil description base on its reddish color, drainage quality, and its versatile agricultural use. This site was chosen because those who work and live there have many years of experience in the production of rice and in the conduct of experimental tests. In addition, the Kakanitchoé site has a training center for young agricultural entrepreneurs growing rice. The young farmers operating on this site produce upland, plateau, and lowland rice.

Farmers that were surveyed received the same weeder used in fields tests were from four regions in southeastern Benin: Oueme, Plateau, Zou, and Collines (Figure 12). Participants from these regions had similar soil conditions to Kakanitchoé's, however it must be noted that those located in areas with heavy clay content (vertisols and gleysols) were excluded because of the inability to use the weeder in unflooded conditions.

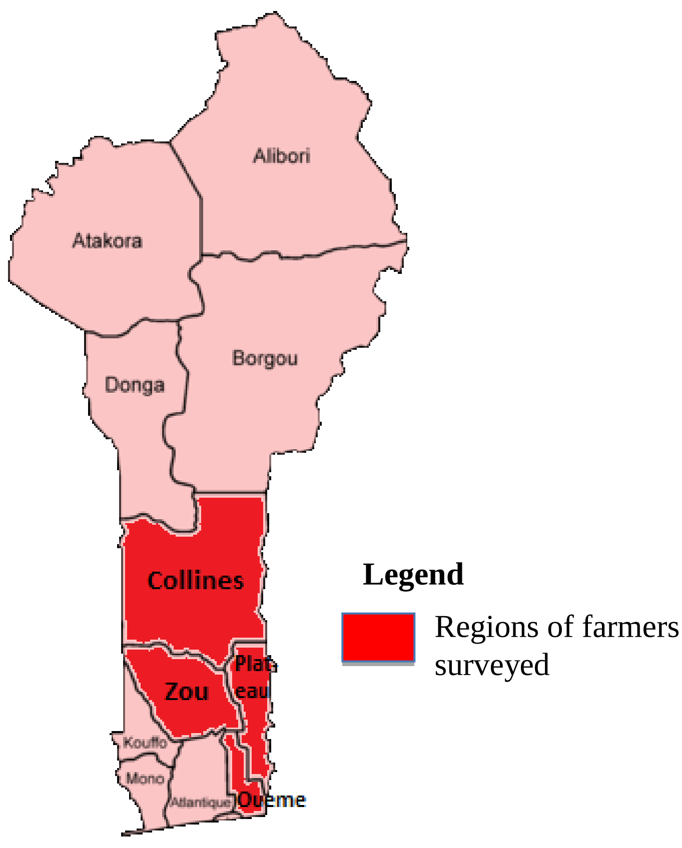

Figure 12. Regional locations of farmers surveyed. Modified by author from Wikipedia, 2009

3.2 Study Participants

3.2.1 Partners

Partners involved in this evaluation and study include the Union of Rice Farmers of the Oueme Plateau (URIZOP), Consultation Council of Rice Producers in Benin (CCR-B), and Farm SAIN. URIZOP is primarily a rice processing facility that hulls locally harvested rice and offers slightly better prices than simply selling rice on the market (by about 10-20 FCFA per kilo/0.02-0.04 USD), though newer rice farmers seem to face difficulty entering the cooperative. Rice processed by URIZOP is also packaged and sold locally. Unfortunately, the quality of rice suffers because the machines used are old and there are no alternative machines are available, as there is typically one machine per facility. As such, they hire women to pick through the machine-hulled rice to remove impurities. The remaining rice bran is sold to farmers who use it for compost or animal/fish feed.

CCR-B serves as the national organization of rice producers throughout Benin and has a branch in every commune where smaller associations of rice farmers are formed. Since its establishment in 2006, CCR-B has worked to unionize and advocate for strengthening the capacity of rice farmers. CCR-B was founded by Pascal Gbenou, a devoted rice farmer and owner of Farm SAIN. Farm SAIN primarily serves as an educational and training facility for young Beninese farmers who serve 18 month apprenticeships and learn both theoretical and practical aspects of farming. The facility also hosts trainings for CCR-B members and welcomes farmers, students, and visitors from around the world.

3.2.2 Selection of Farmers

With the aid of URIZOP and the CCR-B, 30 farmers in the Oueme, Plateau, Zou and Collines regions were selected to participate in the study that would require them to use a mechanical weeder for the duration of the growing season beginning in December 2015 and concluding in May 2016. During this time, half of these farmers would be selected to be surveyed to evaluate their experiences with the weeder. Other farmers located in central and northern Benin will be testing the weeder between June 2016 and October 2016, their respective rice cultivation season, however the results from their experimentation are outside the limitations of this paper.

Field trials comparing weeding times of the mechanical weeder to hand weeding were controlled tests conducted at Farm SAIN and were separate from the farmer surveys. Beyond the simple scope of this study, the larger goal is to use the results learned from survey participants in editing the study's chosen weeder so that it can be better adapted to local ecological conditions.

3.3 Experimental Design

3.3.1 Field tests

At Farm SAIN, eight experimental plots of rice measuring 400 m^2 were planted in accordance to best management practices (BMPs) and maintained by farm apprentices and female rice farmers. Specifically, each plot of transplanted rice spaced individual plants 25cm x 25cm apart. The plots were evenly divided (four and four) to be weeded either by hand (without a hoe or small instrument) or with the wheel hoe weeder, the weeder specifically imported and locally replicated for the experiment. Each plot was timed at the start and completion of each weeding session. The four plots weeded by hand used five (5) men and five (5) women each, but were not differentiated by gender. The resulting time was multiplied by ten (10) to discover the time for one person to weed each plot. With use of the wheel hoe weeder, women weeded plots two (2) and three (3), and men weeded plots one (1) and four (4).

The results found from these tests were not numerous or significant enough to run a full statistical analysis, however simple comparisons could be made between overall weeding times and some weeding times differences between genders. These were analyzed using simple Excel.

3.3.2 Farmer surveys

With the aid of URIZOP and CCR-B, 30 rice farmers were selected to participate in evaluating the utility of the wheel hoe weeder, the selected weeder was also used in the experimental field tests. These farmers, located in four regions in southern Benin (Figure 12), received one (1) wheel hoe weeder and were asked to use this weeder throughout the growing season (December 2015 to May 2016) at their respective locations in Benin (Figure 13). From the 30 that used the weeder, 15 farmers were selected as representative of those regions to respond to a total of fourteen (14) survey questions (Appendix 1) created and revised by URIZOP and CCR-B to better understand the benefits of the weeder, its limitations or disadvantages, and the conditions to promote its adoption. The fourteen statements were divided based on the following categories: the advantages of the weeder (questions 1 to 6); the constraints of weeder (questions 7 to 10) and measures to encourage the adoption (questions 11 to 14). The statements were graded using a Likert scale with the left end of table expressing the strongest disagreement and the right end expressing the strongest agreement. The middle position of the table demonstrated a neutral or indifferent response.

Figure 13. Farmer using wheel hoe weeder in his respective field. Source: Author's own

The fifteen (15) weeder recipients participating in the field surveys included: producers in the Oueme and Plateau regions (5), producers in the Zou and Collines regions (5), female producers from all four regions (4), and extension workers/researchers in the Plateau (1).

Participants were individually and privately interviewed by selected readers who were required to explain the survey and translate each statement into local language to ensure full comprehension. Participants were allowed to change their response at any time.

The survey results were reviewed by comparing by the percentage of individuals who had similar responses and then analyzing their response in the context of the question and farmer conditions in Benin. A full analysis was not conducted because the number of participants was low and the questions posed were easier to review in context rather than in data form.

CHAPTER 4

RESULTS

4.1 Field Tests

The overall results demonstrate an average difference of 385 minutes, or a little less than 6.5 hours, between the time it takes to weed by hand than to weed with a weeder, illustrating that the weeder reduces weeding times by approximately 80% (Table 1).

Table 1. Weeding times

	Minutes (One Person/400 m^2)	Hours (One Person/400 m^2)	Hours (One Person/Hectare)
Hand 1	453.60	7.56	189.00
Hand 2	448.35	7.47	186.81
Hand 3	503.50	8.39	209.79
Hand 4	544.50	9.08	226.88
Average	487.49	8.13	203.12
Weeder 1	108.60	1.81	45.25
Weeder 2	91.63	1.53	38.18
Weeder 3	99.84	1.66	41.60
Weeder 4	109.20	1.82	45.50
Average	102.32	1.71	42.63

Source: Field tests, 2016

The fourth column demonstrates the total man-hours required to weed one hectare (10,000 m^2) of rice results that were found by multiplying the total number of hours one person takes to weed 400 m^2 by 25.

In regards to the difference between genders, men and women were undifferentiated when weeding by hand as they weeded the plot silmultaneously, however when weeding with the mechanical weeder women on average weeded 13 minutes, or 12%, faster than men (Table 2).

Table 2. Gender differences in mechanical weeding times

	Minutes (One Person/400 m^2)
Female – Plot 1	108.6
Female – Plot 4	109.2
Female Average	108.9
Male – Plot 2	91.63
Male – Plot 3	99.84
Male Average	95.74

Source: Field tests, 2016

4.2 Farmer Surveys

Using a Likert Scale, eleven (11) male and four (4) female participants were surveyed on their perception of the weeder based on the weeder's utility, the users' satisfaction with the weeder, and the weeder's potential. For a majority of statements, participants generally agreed (Figure 13). Very few led to an indifferent or disagreeable response. The more notable statements posed were where a strong majority or feeling towards one response was noted for statements #1, 4, and 14.

Statement #1, the weight of the weeder, was notably agreeable for all participants. While this may appear as a relatively insignificant response, an agreeable response towards the weeder's weight provides a benchmark for favorable weights of weeding tools for smallholder farmers, particularly those who have to walk a considerable distance to tend to his or her rice field.

Statement #4 shows a 47% indifference or neutral attitude towards whether the weeder alleviates back pain. The general neutrality may be a sociological disposition (participants may be well accustomed to back pain when tending to the field) or it is demonstrative of the limited time frame of the experiment.

Statement #6's general agreement points to an added use of the weeder: its versatility with other garden crops, demonstrating a benefit of the weeder's use and potentially its return on

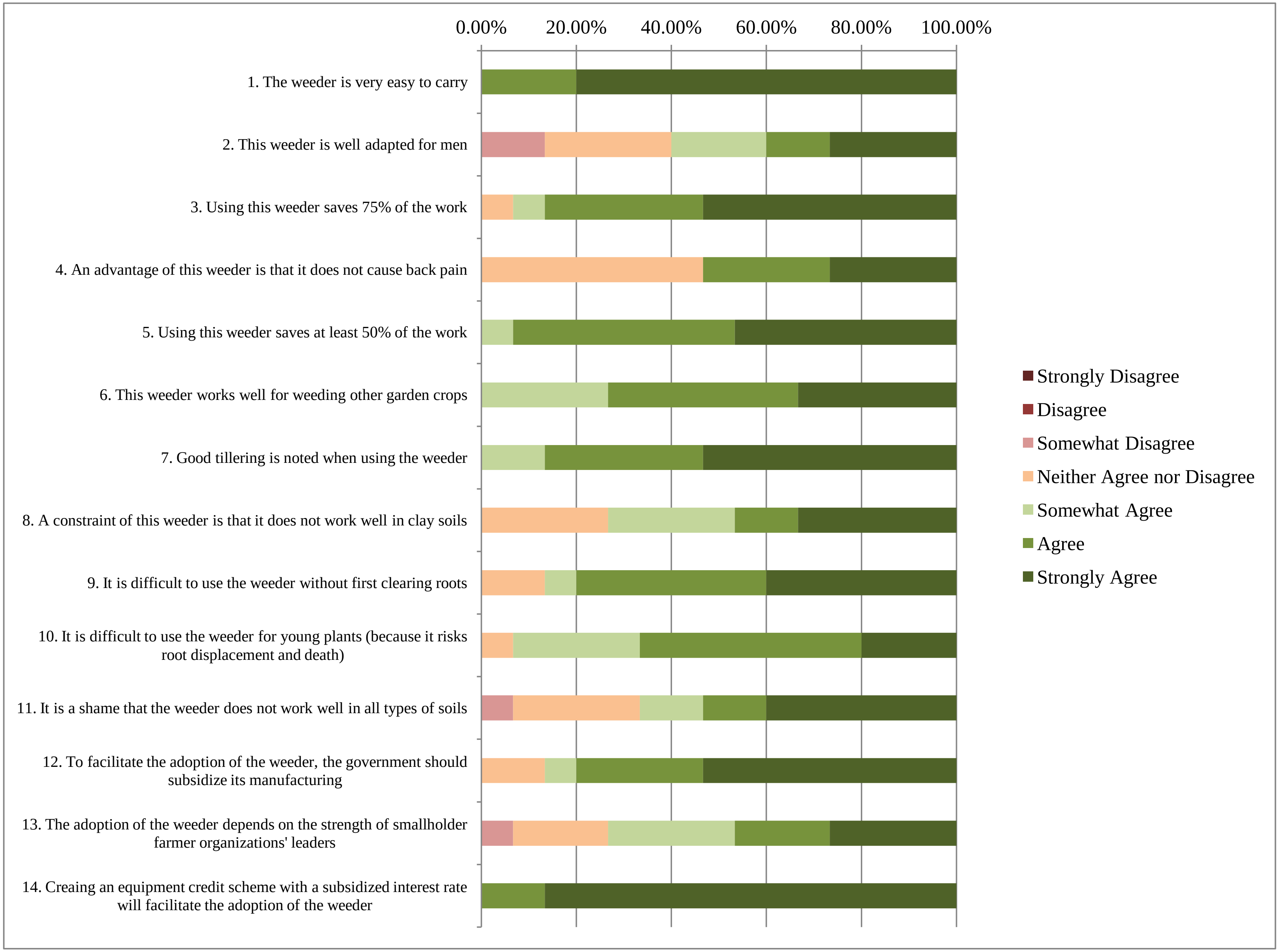

Figure 14. Survey results. Source: Survey results, 2016

investment for a smallholder farmer. This also speaks to Statement #7's general approval, as the benefits to crops are suggestively visible to farmers.

Statement #14 poses a question about the adoptability of the weeder using a credit scheme. The almost unanimous response (86% strongly agree) demonstrates a strong indication towards the potential of marketing tools for smallholder farmers. However, as this survey indicates, not every aspect of the weeder used during this study was well adapted for all users (#2, for example, points to this fact). Thus, modeling adaptable weeders through participatory trials on varying soil conditions is a favorable means of achieving farm adoption and investment in simple weeding technologies.

Less polarizing statements also point to inconsistencies in the weeder or its implementation. As mentioned above, Statement #2 suggests that the weeder is not necessarily well adapted for universal use calling into question gender differences and individual shortcomings when operating a mechanical push weeder.

Statement #11's 33% of slight disagreement or indifference possibly shows that participants understand the unique utility of this one weeder used in the experiment, suggesting that not all weeders can conform to one soil type.

Finally, Statement #13 seems to express the unnecessary role that leaders of farmer organizations possess in the adoption of advanced technologies, suggesting that perhaps individual incentive or situations play a stronger role.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

Results from the field tests demonstrate what is commonly understood about the efficacy of mechanical weeders: they reduce weeding time over simply weeding by hand. Under the field tests conducted in this study, weeders reduced weeding times by an approximate average of 80%. This is consistent with studies by Hobbs & Bellinder (2004) and Rodenburg et al. (2015).

The reduction in time it takes to weed has significant economic impacts on farmers as well (Melander & Rasmussen, 2000; Ramahi & Fathallah, 2006; Remesan et al., 2007). Though work hours are variable throughout Benin, the rate for two hours of weeding is typically 1,500 FCFA ($3 USD). Based on the results, farmers could save approximately 40,000 FCFA ($80 USD), or 4.7 times the cost for weeding one hectare of land (assuming that the land owner hires out all of their weeding-related labor). This is slightly less than costs reported by Remesan et al. (2007), who calculated a reduction between 5 to 7 times that using a mechanical weeder versus hand weeding.

The introduction of mechanical weeders also incentivizes smallholder farmers to farm in accordance to BMPs, one of the more difficult behavioral changes to realize in SSA. Weeders require adequate spacing, which, like weeding, leads to increased yields. Due to the limited timeframe of this study, results on yield could not be compared. However, as previous studies have suggested, weeding does reduce yield loss (Akobundu, 1980; Becker et al., 2003; Johnson et al., 2004; Rodenburg & Johnson, 2009).

The mechanical weeder also has the potential to change the dynamic between masculine and feminine roles in labor activities. The reduced weeding times between the women and men that used the weeders is a notable example of how stereotypical roles can change with the introduction of a new and efficient mechanism. Because it takes less time to weed, men who own their fields are more inclined to weed their own field and not require external labor. Equally, women are freed from tedious, back breaking labor. While this could offer additionally time for alternative income generating activities, as suggested by N'cho (2014), it could also create a displaced workforce.

This study contributes to the dialogue mentioned by several researchers who state that testing weeders for an entire season to examine the adoption of adapted weeders best determines their shortcomings (Rodenburg et al., 2015; Singbo & Lansink, 2009; Gongotochame et al., 2014). As Rodenburg et al. (2015) writes, "the type of rotary weeder should be… adapted to local conditions or be selected through farmer participatory tests." This study aimed to achieve this goal by using a potentially universal weeder for both the field experiments and the farmer surveys. Further, the farmer surveys aided in confirming or realizing certain qualities and the impact of weeders for rice farmers in Benin, namely a weeder's weight (for ease of transport to the field and for non-gender specific use), the weeder's versatility (its use for other crops), and the interest of farmers in having an available credit scheme in order to purchase weeders for regular use. These finding were similar to studies conducted in India by Senthilkumar et al. (2008) where the farmers' perceptions of the weeders were based on their workability in soils (in this case, upland and plateau) and the weight and comfort of the weeder. The questions in this survey were not extensive enough to demonstrate a significant divergence amongst gender, as found in their respective study, however it can be suggested that differences in weeding times between genders from the field tests shows slightly more comfort with the study's mechanical weeder.

This study points to an important yet overlooked aspect of agricultural development in Benin: the implementation of simple technologies. By allowing farmers to test weeders themselves and by demonstrating a weeder's overall efficiency in labor time through field tests, farmers are better able to fully understand the utility of weeders, a key aspect in the adoption of weeders as noted by Gongotochame et al. (2014).

However, this study was certainly not fully comprehensive. Limitations of the work include: missing details from field tests including yield and tillering; experimental field tests were conducted only on one agroecological zone while Benin has a total of eight (8); lastly, rice production is greatest in the central and northern region of Benin, areas where rice cultivation begins in June, thus to have been more representative these areas should have been taken into account. Subsequent work will not only extend the experimental field of this tool for weeding but also to analyze in depth the time working on different soil types.

To further the findings of this study, it is recommended that additional participatory tests be implemented by either using weeders that have been adapted by farmer groups or creating custom weeders so that they work best under their region's soil conditions. For example, cono-weeders, which are popular for flooded clay soils, are not as convenient for farmers to carry to their fields and require the soils to be completely flooded in order to work well. By making small modifications to this weeder, it may be possible to make it less cumbersome and more appealing to smallholder farmers.

Additionally, a closer look at the impact weeders have on gender, specifically in Benin, is also a worthy endeavor. As noted in this experiment, the use of weeders may in fact change the gender dynamic or simply lessen the burden put upon women in agriculture.

Lastly, outside of research, the general availability of weeders for rice farmers and payment schemes to purchase them are the more crucial steps towards developing the standards and practices of smallholder farmers. There is a large demand for improved technologies yet not enough resources to realize this request.

CHAPTER 6

CONCLUSION

A crucial staple for the population of Benin, rice, has, in recent times, seen a surge in its import and production because of its appealing qualities to consumers. However, demand is quickly outpacing supply and there is little being done to support smallholder farmers in Benin and elsewhere in producing the quantity and quality of rice needed.

The advancement and adoption of simple technologies such as mechanical push weeders is a small but useful tool in aiding the development of rice fields in this region of the world, reducing overall labor time in the field, increasing farmers' income, and improving rice production. The intent of this study was to both implement a simple mechanical weeder and evaluate its strengths and weaknesses through farmer surveys and controlled field tests. Much like previous studies have found, the weeder effectively reduced weeding time, significantly lessening the labor time required of rice farmers. Further, the surveys demonstrated a positive reaction to the utility of the weeder in relation to its efficiency, weight, multiuse, and potential for continued use and adoption. While participatory tests are necessary for the continuation of these findings, it is a small step forward for the advancement of smallholder Beninese rice farmers and, in time, rice farmers of West Africa.

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Appendix A. Farmer Survey

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewh at Agree	Agree	Strongly Agree
1. The weeder is very easy to carry							
2. This weeder is well adapted for men							
3. Using this weeder saves 75% of the work							
4. An advantage of this weeder is that it does not cause back pain							
5. Using this weeder saves at least 50% of the work							
6. This weeder works well for weeding other garden crops							
7. Good tillering is noted when using the weeder							
8. A constraint of this weeder is that it does not work well in clay soils							
9. It is difficult to use the weeder without first clearing roots							
10. It is difficult to use the weeder for young plants (because it risks root displacement and death)							

11. It is a shame that the weeder does not work well in all types of soils							
12. To facilitate the adoption of the weeder, the government should subsidize its manufacturing							
13. The adoption of the weeder depends on the strength of smallholder farmer organizations' leaders							
14. Creaing an equipment credit scheme with a subsidized interest rate will facilitate the adoption of the weeder							