東京大学 大学院 新領域創成科学研究科

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修　士　論　文

Integrated Analysis on Technology Adoption and Its Impact of Sawah Project in Nigeria.

技術採択とその影響に関する統合的分析：
ナイジェリア国サワプロジェクトを事例として

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本論文は，修士（国際協力学）取得要件の一部として、2010 年 1 月 21 日に提出され、同年 2 月 1 日および 2 日の最終試験に合格したものであることを、証明する。

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主査________________________________

Abstract

For several decades, many sub-Saharan African countries have been facing the issues of persistent food shortages and poverty reduction. In West Africa, there are about 20 million hectares of inland valleys, much of which can be used for wet rice cultivation. However, much of this land is unused, or used with traditional cropping systems with low productivity. Sawah technology is known as a highly productive and sustainable rice farming system, which is spreading as a technology in Nigeria and Ghana. A great deal of effort has been made on the environmental assessment of biophysical conditions; however, the accumulation and assessment of quantitative data is lacking.

This study aims to define the determinants of adopting Sawah technology and its impact on rice yield and income, as well as to provide strategic information for technology diffusion. The result of this study can contribute to encouraging further diffusion of technology in other African regions.

This study adopts and integrated approach to obtain a quantitative understanding of the issue. Namely, the study is based on an econometric analysis of household and field surveys. The spatial information was collected by field surveys and converted into GIS-derived variables (i.e. the distance to the plot and slope rate). A Multinomial Logit model and 2SLS were also employed to determine the impact of adopting Sawah on rice yield and income, respectively.

From the Analysis, I have found that economical factors are significant determinants for adopting Sawah. However, farmers who could not adopt Sawah copied the essence of the technology and have created an innovative and suitable cropping system referred to as *Semi-Sawah*. *Semi-Sawah* is an easily adoptable technology, and thus farmer characteristics do not have an effect on the adoption of this technology. The most important determinants for adopting *Semi-Sawah* are plot characteristics. Farmers make a selective decision on adopting *Semi-Sawah* by considering the conditions of their plot.

As for rice yield and income, it is revealed that Sawah increases both yield and income, whereas *Semi-Sawah* only affects on rice yield.

Finally, I use the results from estimation to illustrate the plots that have high potential for adopting Sawah technology and verify the possibility of diffusing Sawah by farmers’ self efforts.

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Chapter 1:
Introduction

Farmer is leveling his paddy field.

(Photograph is taken in Ejiti, 09/23/2008)

1.1. Background

1.1.1. Priority for Africa

Poverty reduction and food security in sub-Saharan Africa (SSA) are of major priority issues. Since the United Nations articulated eight goals, well known as the millennium development goals (MDGs), toward the global issues, many involvements were carried out to the will of the world. Poverty reduction was set up as first goal of MDGs; however Sahn and Stifel (2003) predict that the most of sub-Saharan Africa (SSA) regions have no progress on poverty alleviation. According to the World Bank (2008), most of the poor people in developing countries live in rural areas and most of them engage with agricultural activities. Therefore, enhancing the empowerment of small householders in rural area is the key to poverty reduction.

SSA is facing another issue, food shortage. Recent years, consumption of rice in SSA is drastically increasing due to population growth and demand from urban region. Figure 1-1 shows rice production and consumption, as well as import of SSA countries. It is obvious that differential between production and consumption is varying greatly and dependence on import, in proportion, is increasing from 90s.

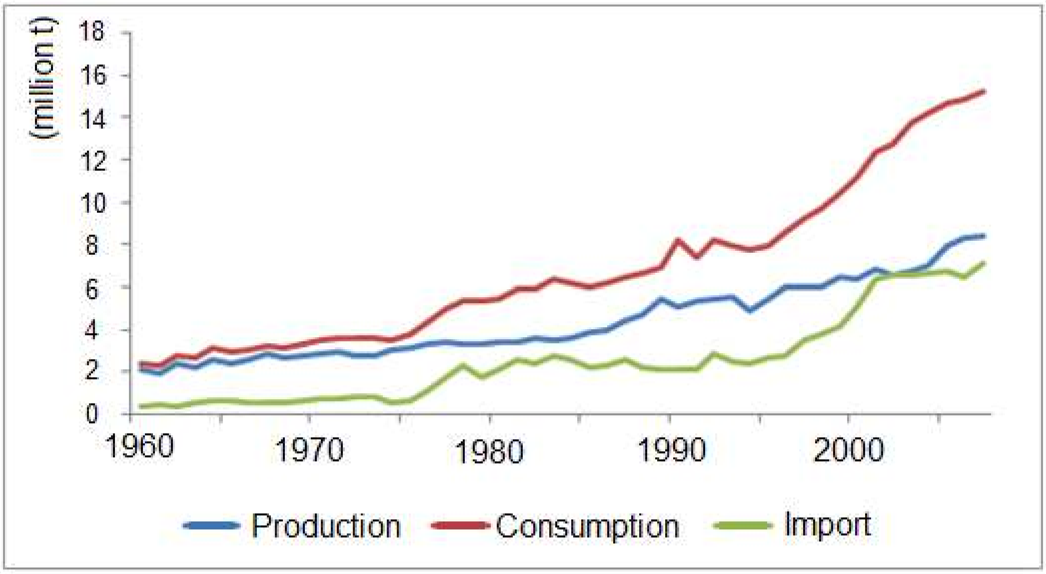


Figure 1-1: Production, consumption, and import of rice in SSA
(Source: World Food Statistics and Graphics)[1]

1 World Food Statistics and Graphics
URL: http://worldfood.apionet.or.jp/graph/index-e.html

To deal with this rapid augmentation of rice, many African countries use foreign exchange for purchasing import rice, which is obstacle for economical development (Wakatsuki, 2008). The World Bank (2008) also insists that most of SSA countries depend on agriculture as main industry; therefore, improvement of agricultural productivity has a strong effect on ensuring food security, as well as improving economic growth. Hence diffusion of high productive and profitable agricultural technologies is necessary.

1.1.2. Sawah Technology

According to Wakatsuki (2008), there is about 20 million hectare of inland valleys are prevalent in West Africa, many of which are suitable for wet rice cultivation but are often out of use or used under a low productive traditional cropping system. Wakatsuki (2008) emphasized its potential of agricultural development in the inland valley; the effective strategy for rice cultivation is necessary.

Sawah technology is known as highly productive and sustainable rice farming system, which indicates leveled and bounded paddy fields having flooding water with inlet and outlet canals for irrigation and drainage (Hirose and Wakatsuki, 2002).In addition to this, Sawah fields are paddled by using small size of power tiller. The term Sawah originates from Malayo Indonesian. Because English term “Paddy” includes upland rice field in West Africa, the technology was named as Sawah to avoid confusion.

Since late 1980s, a Japanese interdisciplinary research group has launched an on-farm action research on extension of sawah technology in Bida, Nigeria. Most of this periods, a considerable number of studies have been made on environmental assessment of biophysical conditions of some benchmark inland valley sites, traditional agricultural systems of Nupe and Fulani, and adaptability of sawah technology; the research achievements are given by Hirose and Wakatsuki (2002). There has, however, been no prior study investigating the determinant of adoption of Sawah technology and its impact on farmers by using quantitative data.

1.1.3. Primary Study

Feasibility study was taken place from August to October in 2008 by author. Four villages were selected as target site and 96 household heads were interviewed. In this primary study, paddy fields were simply divided into two, i.e. developed field and traditional field, and rice yield survey was conducted. The yield survey revealed that developed paddy field yielded 2.8±1.1 t ha^{-1}, whereas traditional field is 1.4±0.8 t ha^{-1}. The developed paddy fields called more hired labor cost; however, developed paddy fields earned more net-income which is including self-expenses for labor than traditional fields: respectively 397±411 US$ ha^{-1} and 264±706 US$ ha^{-1}. The findings of this primary study were presented at Japan Association for African Studies in 23rd of May 2009 (See Appendix C).

The results of the primary study show some achievements of developed fields; however, this primary study only grasps the general description of the research area and is not describing in detail. For example, the term "traditional field" which is used in primary study can be divided into several kinds of traditional cropping systems and some respondents answered their paddy fields as Sawah fields even these plots did not meet criteria of Sawah technology which is mentioned above. Most importantly, the determinants of adoption and real efforts on yield and income are yet unclarity.

1.1.4. Review of Prior Studies

A large number of studies have been made on adoption of agriculture technology and impact assessment on agricultural technology. Polson and Spencer (1991) used Probit and Logistic model to estimate the adoption decisions on new variety of Cassava which is high yielding and resistant to common diseases by multicrop producers. The results of their studies revealed that age and migrant, as well as effort from extension agents effects on seed adoption. The positive effect from extension agents is confirmed in other study by Nkonya et al. (1997) who focused on adoption of improved Maize seed and fertilizer in Tanzania, yet this study emphasizes importance of educational level of each producers and heterogeneity of the faming population. Adesina et al. (2000) who researched on alley farming in Cameroon also insist recommendation from researchers is one of significant determinants of technology adoption.

These studies mentioned above focus on farmer's characteristics, farm characteristics, and external factors; however, there is little attention on spatial structure. Some studies employ spatial characteristic, yet they are typically dummy variables. As Staal et al. (2002) insist, dummy variables may capture a wide range of locational effects, whereas differentiating and interpreting micro-level phenomenon are impossible. Research on technology adoption often fails to grasp the detail spatial information.

1.2. Objective of study

This study aims to show that the determinant of Sawah technology adoption and its impact on rice yield and income, as well as to show harmonization of econometric analysis and GIS-derived information. One of the originality of this study is that unit of spatial analysis employs vector data of paddy plot, not grid data. Vector data can extract spatial information of each plot. In addition to the objective mentioned above, this study aims to illustrate the result from econometric analysis on a map to discuss future development of the research area, whereas many of studies stop when econometric model is analyzed and results come out.

1.3. Research Questions and Theoretical Hypotheses

The fundamental question of the study is: "*What are the determinants of adoption of Sawah technology, and have local farmers benefited from Sawah technology?*" Three theoretical hypotheses to answer to the research question are as follows;

Hypothesis (1) "*Increment of economical factors induces adoption of Sawah technology.*"

Since developed fields exact more cultivation cost, as stated in primary study, farmers whose economical condition is comparatively rich than others are conceived to adopt Sawah technology.

Hypothesis (2) "*Farmers copy the essence of Sawah technology and innovate it to suitable cropping system.*"

Since power tiller is necessary to cultivate Sawah, farmers who cannot use power tiller are impossible to cultivate Sawah even if they want to. The second hypothesis of this study is that these farmers copy the essence of Sawah technology and innovate it to suitable cropping system. The suitable cropping system means the easily adoptable technology. More specifically, even relatively poor farmers adopt the technology and cultivators' characteristics have no effects on the adoption, as well as the spatial conditions of plot are more important determining factors than cultivators' characteristics.

Hypothesis (3)　　“*Farmers benefit from Sawah technology.*”

In order to define the benefit for farmers, it is important to test the effort of Sawah technology on rice yield and income. Insistence of this study is that Sawah technology effects positively on both yield and income, even considering with other factors.

1.4. Structure

In chapter 2, the original data which is taken from field survey conducted in 2009 is described. In this chapter, the GIS-derived variables are examined by using spatial analysis. In chapter 3, the determinant of adoption of technologies and its impact on rice yield and income are analyzed by integrated econometric analysis, which is using the data presented in the chapter 2. Chapter 4 presents application for future development. Chapter 5 furnishes discussion and concludes this paper.

Chapter 2:
Data and Sampled Households

Farmers are transplanting rice seedling.
(Photograph is taken in Nassarafu, 08/09/2008)

2.1. Site Description

The research was conducted in Bida (9˚08’ N, 6˚01’ E), Niger State, central Nigeria. The vegetation of the research area belongs to Guinea savanna zone. A year is divided into two seasons; wet season starts from May to October and dry season starts from November to April. The mean annual temperatures are 23-24 Celsius and yearly precipitation is about 1,100mm.

Nupe, the dominant ethnic group, engages in lowland rice cultivation during the rainy season. Nupe has a long established several varieties of rice farming system.

Sawah technology was first introduced to Bida through on-farm research which was conducted by IITA (International Institute of Tropical Agriculture) during 1986-1989. The research was only focused on experiment of rice varieties and effects of fertilizers, therefore Japanese scientists resumed participatory trial to demonstrate Sawah technology to Nupe farmers during 1992 to 1997. The demonstration fields yielded higher than local cropping system; however, the adoption of Sawah by farmers was unsuccessfully. One of the reasons of poor adoption is that Sawah technology was introduced by Japanese scientists, not by local Nigerian. In an effort to promote Sawah technology, a local NGO, Watershed Initiative in Nigeria (WIN) was established in 2001. The real efforts for diffusion of Sawah technology was launched from 2003.

2.2. Target area

2.2.1. Field work

Main enumeration was conducted during the period June to August in 2009. Eight villages were selected for the household survey. Out of these five villages, four (Shabamaliki, Nassarafu, Ejiti, and Emitsundadan) were being involved in Sawah dissemination program by NGO WIN and rest four (Emiworongi, Amgbasa, Tswatagi, and Emitsu) not. As the Figure 2-1 indicates, five villages (Shabamaliki, Nassarafu, Emiworongi, Tswatagi, and Emitsu) are located at a short distance in southwest from Bida. Emitsundadan is in between Bida and Doko market. Other two villages (Ejiti and Amgbasa) are located west from Doko market. Points of Village and market which are shown in Figure 2-1 were geo-referenced using a GPS unit; meanwhile, points are combined with satellite photograph sourced from Google Earth by author.

Complete count survey was attempted; however, only135 heads of rice-producing households are identified out of 161 were interviewed by original questionnaire which was referred to one of the

World Bank's questionnaire. All of them embrace Muslim. The paddy fields which were cultivated by interviewed farmers were majored by using a GPS device (Garmin GPSMAP60CSx). The paddy field data of 132 farmers were majored perfectly and some of the data from remain three farmers are missing; therefore these 132 farmers' data, henceforth, is used for analysis. The total number of paddy fields is 319. Statistical analysis and spatial analysis were done using software: respectively Stata 10 and ArcGIS 9.3.

Figure 2-1: Locations of Bida and research sites

Source of background image: Google Earth

2.2.2. Definition of Rice Cultivate System

Nupe farmers, as mentioned above, have several traditional rice cropping systems. Around the research area, three traditional methods were identified: Gbaragi, Baragi, and Togogi/Togoko naafena.

According to Ishida (2002), Gbaragi has linear parallel ridges, about 30-50 cm in height and 30 cm in width, and farmers plant rice on it directly. Baragi is a flat rice field with soil turning over by hoe, and usually directly planting. Togogi naafena and togoko naafena have hook-shaped ridges, which height is about 30-70 cm, within each block. Difference between Togoko naafena and Togogi naafena is size, i.e. Togoko naafena is bigger than Togogi naafena. Since number of samples of Togoko naafena and Togogi naafena are limited, thus Togoko naafena and Togogi naafena are merged as Naafena. From field research, 189 paddy fields out of 319 were identified as traditional fields.

Rest of 130 paddy plots was identified as Sawah which is known as paddy field paddled by power tiller; however, farmers also call paddy field plowed by man power not by power tiller as Sawah. According to listening from farmers, farmers copy the essence of Sawah technology and alter the cropping system to fit into farmers' condition, though, they do not discriminate between real Sawah and man power imperfect Sawah. Man power imperfect Sawah has a mound about 40-60 cm in height and 0.5-1 m in diameter in the middle of the field. A couple days before transplanting, farmers break the mound and spread to make a soft flat surface by using hoe. To distinguish real Sawah and man power imperfect Sawah, the term "Semi-Sawah" is used to refer to man power imperfect Sawah. Since Sawah demands power tiller for cultivation, Sawah plots can only be identified in villages which power tiller is delivered by NGO WIN. Semi-Sawah plots, on the other hand, cultivated widely because cropping system of Semi-Sawah was spilled over to other villages. In the research area, 29 Sawah fields and 101 Semi-Sawah were found. Number of observations, classification of cropping system, and definition are listed in Table 2-1.

Table 2-1: Number of observations and characteristic

Local name	n	Classification	Definition in this paper
Sawah	29	Soil is plowed deeply by Power tiller.	Sawah
Sawah	101	Soil is plowed shallowly by man power using hoe.	Semi-Sawah
Gbaragi	140	Soil was plowed by hoe and formed linear parallel ridges.	Gbaragi
Baragi	43	Soil was plowed by hoe and turn over.	Baragi
Togogi-Naafena Togoko-Naafena	6	Soil was plowed by hoe and formed hook-shaped ridges.	Naafena

Characteristic of each cropping system is shown in Table 2-2. Row of Transplanted indicates number of fields transplanted. As it shows, paddy fields of Sawah and Semi-Sawah were transplanted while almost every traditional fields were planted directly. Most of farmers chose WITA4, improved rice variety, for Sawah and Semi-Sawah. Distance from center of village is provided in Table2-3. It indicates that Sawah and Semi-Sawah fields tend to be cultivated close to villages than traditional fields.

Table 2-2: Number of field transplanted and used WITA4

	n	Trans planted	WITA4	Fertilizer
Sawah	29	29	28	25
Semi-Sawah	101	101	95	76
Gbaragi	140	0	18	84
Baragi	43	4	7	27
Naafena	6	0	3	5

Table 2-3: Distance to paddy field from each village (km)

District	Sawah	Semi-Sawah	Gbaragi	Baragi	Naafena
Shabamaliki	N/A	0.74 (0.49) n=28	3.25 (0.59) n=13	1.39 (0.85) n=16	N/A
Nassarafu	1.33 (0.21) n=19	1.66 (0.22) n=9	1.70 (0.32) n=41	1.20 (0.14) n=2	N/A
Ejiti	0.60 (0.12) n=10	0.64 (0.13) n=16	2.84 (3.07) n=20	N/A	N/A
Emitsundadan	N/A	1.77 (0.40) n=21	N/A	N/A	1.53 (0.49) n=6
Emiworongi	N/A	0.63 (0.30) n=18	1.52 (0.59) n=21	N/A	N/A
Amgbasa	N/A	N/A	6.70 (0.90) n=18	N/A	N/A
Tswatagi	N/A	0.34 (0.34) n=5	1.28 (0.39) n=15	0.45 (0.33) n=16	N/A
Emitsu	N/A	0.70 (0.29) n=4	0.93 (0.39) n=12	0.40 (0.09) n=9	N/A
Average	1.08 (0.40)	0.98 (0.62)	2.51 (2.14)	0.82 (0.72)	1.53 (0.49)

The numbers in parentheses are standard deviations.

2.2.3. Sample households

Basic information of villages and household heads interviewed is given in Table 2-4. Four villages listed from top are villages which are participated to Sawah program and bottom four are non-participate villages.

Other than village Emitusndadan, average area of cultivated paddy field is about 1-2 hectares. Average distances to each paddy field are mostly within 2km; only farmers of village Amgbasa cultivate paddy fields 6.7km far from village.

132 farmers are classified into three groups: Sawah farmer, Semi-Sawah farmer, and Traditional farmer (Table 2-5). Sawah farmer, 21 farmers out of 132, includes farmers who adopted Sawah and traditional cropping system. Sawah farmer adopted averagely 36.0 percent of the total paddy area as Sawah and 63.4 percent as one of traditional method. Only one farmer from Sawah farmer group adopted both Sawah and Semi-Sawah, therefore proportion of Semi-Sawah marked 0.6 percent. Semi-Sawah farmer is a group from 80 farmers which adopted Semi-Sawah and traditional method, which proportions are respectively 57.5 percent for Semi-Sawah and 42.5 percent for traditional method. 31 farmers out of 132 chose one of traditional method, which define as Traditional farmer group.

Table 2-4: General information of research site

Participatory of Sawah program	District	Total number of heads in village	Number of heads interviewed	Average age of household heads	Number of household members	Average educational year	Average area cultivated (ha/ household)	Average distance to paddy field (km/plot)	Distance to nearby market (km)
Participate villages	Shabamaliki	30	24	39.9 (12.5)	14.0 (6.4)	6.4 (5.0)	0.84 (0.99)	1.49 (1.17)	11.4
	Nassarafu	34	19	43.4 (15.8)	21.8 (16.5)	5.7 (5.2)	2.23 (1.21)	1.58 (0.33)	13.2
	Ejiti	26	24	44.4 (12.0)	14.5 (6.5)	3.2 (4.7)	0.99 (0.67)	1.58 (2.28)	7.4
	Emitsundadan	21	17	35.8 (11.1)	10.4 (6.1)	3.4 (4.4)	0.28 (0.18)	1.71 (0.43)	9.7
Non-participate villages	Emiworongi	19	18	36.6 (8.5)	11.7 (6.9)	5.1 (3.7)	1.09 (0.45)	1.11 (0.65)	13.8
	Amgbasa	14	13	42.0 (15.3)	13.4 (10.1)	7.4 (5.8)	1.06 (0.44)	6.70 (0.90)	7.8
	Tswatagi	9	9	34.0 (8.9)	8.3 (3.2)	6.9 (1.4)	2.06 (0.75)	0.78 (0.55)	13.2
	Emitsu	8	8	41.3 (14.2)	13.1 (7.7)	4.3 (3.1)	1.50 (0.92)	0.70 (0.38)	13.6
	Total/Average	161	132	40.1 (12.7)	13.9 (9.5)	5.1 (4.7)	1.17 (0.97)	1.65 (1.67)	11.3

The numbers in parentheses are standard deviations.

Table 2-5: Number of farmers adopting Sawah and Semi-Sawah

Farmer	Number of farmers	Proportion of Sawah field (%)	Proportion of Semi-Sawah (%)	Proportion of Traditional field (%)
Sawah farmer	21	36.0	0.6	63.4
Semi-Sawah farmer	80	0	57.5	42.5
Traditional farmer	31	0	0	100

Table 2-6 shows per capita income and the share of income sources, as well as the total paddy filed area per household member and share of Sawah and Semi-Sawah, by per capita income quartile. Total income of each household was figured the sum of crop production, livestock production, and non-farm work. Income of crop and non-farm work was calculated as the value of products minus paid-out costs.

Revenue of crop income consists of sales of rice and major off-season crops: eggplant, okra, chili pepper, and tomato. Paid-out costs for crop production include the costs of power tiller, hired labor, seeds, fertilizer, and herbicide. In the case of livestock, income includes only sales of livestock, such as sale of cattle, sheep, goat, chicken, pigeon, and duck. Non-farm work include non-farm microenterprises: Fishery, bike taxi, trading various goods, casual labor activities, and civil servant. Income from non-farm work consists of revenue from dry and wet season minus paid-out cost, such as material and transportation expenses. The last column of table 2-6 indicates whether the means of variables for lower- and higher-income households are statistically different.

There are several important findings in this table. First, the total paddy field area is increasing through quartile 1 to 4, whereas there is no big difference in the total paddy field area per household member among quartile 2, 3, and 4. Since area of quartile 1 is much lower than other three, data shows that there is statically different; however, there are no significance among quartile 2, 3, and 4. Thus it can be stated that quartile 1 is most likely described as land-poor farmers. Also, proportion of Sawah and Semi-Sawah area shows that higher-income households adopted Sawah while lower-income cultivated Semi-Sawah instead. Second, the share of crop and non-farm work income varies considerably across quartile. The lower-income households depend on crop income as main source of income while higher-income households earn half percent of income from non-farm work. Hence agricultural support would affect greatly to lower-income households. Third, the share of rice income is much higher than off-season crops. Especially, lower-income households depend more than half percent of their income on rice income. From perspective of poverty reduction, these findings suggest that introducing high profitable rice system is necessary.

Table 2-6: Per capita income, income sources, by income quartile

	Quartile of income per capita				
	1	2	3	4	
Per capita income (US$)	354	994	1,776	3,837	***
Share of crop income (%)	90	75	40	33	***
Share of livestock income (%)	6	5	13	15	***
Share of non-farm work income (%)	4	20	47	52	***
Share of rice income (%)	70	66	34	28	***
Total paddy field area (ha)	0.65	1.14	1.36	1.55	***
Share of Sawah area (%)	1	2	7	17	***
Share of Semi-Sawah area (%)	43	36	34	25	N.S.
Number of household members	13.7	10.8	14.2	16.9	**
Years of schooling of household head	4.0	5.6	5.0	5.9	N.S.
Total paddy field area per household member (ha)	0.06	0.11	0.12	0.11	**

Asterisk indicates that the means of higher-income (quartiles 3 and 4) and lower-income (quartiles 1 and 2) households are statistically different at significance levels. **=p<0.05 ***=p<0.01 N.S.= Not significant

2.3. Survey on Rice Cultivation

2.3.1. Yield Survey

As a box-and-whisker plot indicates, there was a significant difference in paddy yields between each method (Figure 2-2). The most important finding is that the yield of Sawah is exceedingly high (Table 2-7 and 2-8). The average yield from Sawah (i.e. 3.3±0.5 t ha^{-1}) is twice as large as the average yield of Gbaragi and Baragi (p<0.01). Yield from Semi-Sawah (2.6±0.7 t ha^{-1}) is less than

Sawah field ($p<0.01$), though it produces more yield than fields of Gbaragi and Baragi ($p<0.01$). Sawah and Semi-Sawah yielded more than Naafena; however, there is no significance because number of samples of Naafena is low. Traditional method of Gabaragi and Baragi yielded respectively 1.6±0.8 t ha^{-1} and 1.3±0.7 t ha^{-1}, which corresponds with previous work (Wakatsuki 2008). Yield from Naafena seems high compared with other two traditional fields. Possible explanation will be mentioned in the later sections.

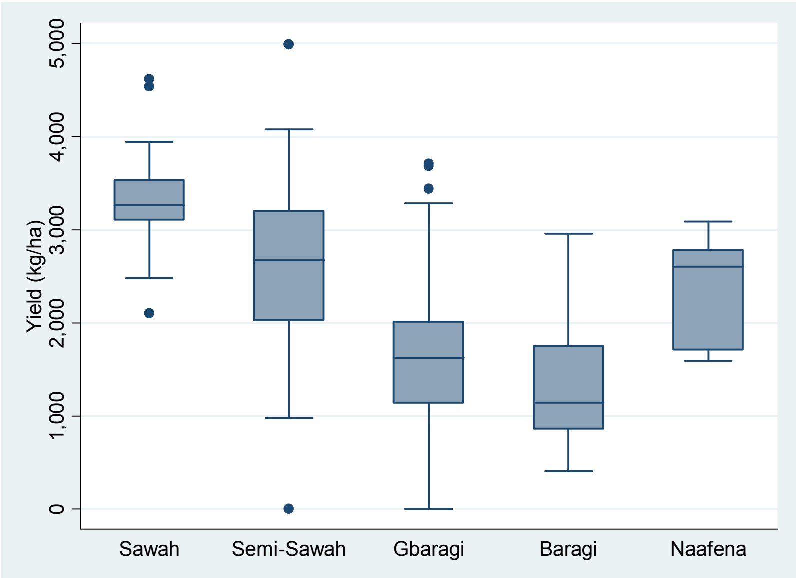


Figure 2-2: Box-and-whisker plot of yield

Table 2-7: Average size and yield from field

	n	Size (ha)	Yield (kg/ha)	SD	Min	Max
Sawah	29	0.54 (0.46)	3,298	539	2,103	4,616
Semi-Sawah	101	0.31 (0.23)	2,603	849	0	4,989
Gbaragi	140	0.59 (0.37)	1,627	754	0	3,708
Baragi	43	0.49 (0.57)	1,320	657	406	2,955
Naafena	6	0.16 (0.16)	2,398	607	1,596	3,089

The numbers in parentheses are standard deviations.

Table 2-8: Difference of average yield between each cropping system (kg/ha)

	Naafena	Baragi	Gbaragi	Semi-Sawah
Sawah	900.3	1,978.0***	1,671.1***	695.3***
Semi-Sawah	205.0	1,282.7***	975.8***	
Gbaragi	-770.8	306.9		
Baragi	-1,077.7**			

**=p<0.05 ***=p<0.01

2.3.2. Production Cost and Net-Income

Table2-9 and 2-10 shows hired labor input and cost of four activities: Land preparation, transplanting, weeding, and harvesting. Labor input is calculated as the numbers of hired people multiply by working days for each activity. Labor cost estimated by calculation of labor input times daily wage per person.

Tables show that Semi-Sawah (US$97.8±86.5 ha^{-1}) demanded more labor in land preparation than Sawah (US$58.3±46.7 ha^{-1}). This difference can be explained by use of power tiller. Sawah uses power tiller; it can reduce labor. Semi-Sawah, in contrast, requires more labor to make and break the mound. The cost of power tiller will be stated in later. Since traditional cropping system is seeded directly, it is clear that transplanting induce incrementation of the cost, i.e. respectively US$146.2±203.3 ha^{-1} in the Sawah US$110.4±114.1 ha^{-1} in the Semi-Sawah while traditional methods are mostly zero. At the end, Sawah and Semi-Sawah called for more total input cost (US$255.4±287.4 ha^{-1} and US$302.4±249.4 ha^{-1}) than two traditional methods: Gbaragi and Baragi.

Table 2-9: Hired labor input[a] of land preparation, transplanting, weeding, and harvesting (man-day/ha)

	n	Land preparation	Transplanting	Weeding	Harvesting	Total
Sawah	29	19.0 (13.1)	46.2 (63.6)	7.5 (13.4)	7.6 (8.5)	80.3 (83.7)
Semi-Sawah	101	44.4 (39.4)	48.2 (47.8)	15.7 (21.1)	25.3 (37.0)	133.6 (110.9)
Gbaragi	140	25.4 (28.2)	N/A	11.7 (15.1)	13.8 (18.9)	50.9 (49.4)
Baragi	43	28.2 (31.0)	2.2 (7.2)	6.4 (7.3)	11.4 (11.8)	48.1 (42.1)
Naafena	6	23.4 (19.9)	N/A	31.4 (40.1)	53.9 (72.4)	108.6 (110.8)

[a] Labor input=working people x working days

The numbers in parentheses are standard deviations.

Table 2-10: Hired labor cost[a] of land preparation, transplanting, weeding, and harvesting (US Dollar/ha)[b]

	n	Land preparation	Transplanting	Weeding	Harvesting	Total
Sawah	29	58.3 (46.7)	146.2 (203.3)	24.5 (48.6)	26.5 (32.9)	255.4 (287.4)
Semi-Sawah	101	97.8 (86.5)	110.4 (114.1)	40.4 (58.5)	53.9 (69.5)	302.4 (249.4)
Gbaragi	140	73.7 (76.4)	N/A	36.2 (51.0)	38.1 (47.8)	148.0 (154.1)
Baragi	43	60.5 (61.7)	4.5 (15.2)	13.2 (14.9)	22.3 (23.2)	100.6 (82.1)
Naafena	6	59.7 (57.3)	N/A	82.7 (103.5)	111.1 (124.2)	253.5 (235.9)

[a] Labor cost=working people x working days x fee

[b] $1 = 116.91 Nigerian Naira

The numbers in parentheses are standard deviations.

Farmers applied more fertilizer to Sawah and Semi-Sawah fields than Gbaragi and Baragi, which was almost double or triple (Table2-11 and 2-12). Surprisingly, input of compounds (NPK) to Naafena is much higher than any other fields. One of the reasons of higher yield from Naafena could be explained by this huge amount of fertilizer.

Table 2-13 summarizes input cost of rice production. For the reason given above, Sawah and Semi-Sawah called for more input cost than traditional methods of Gbaragi and Baragi ($p<0.01$). The cost of using power tiller is only added to Sawah fields (US\$29.6±34.7 ha^{-1}) which includes allowance to operator and expense of diesel oil.

At the last, net-income, which includes self-expenses for labor, is calculated as the value of rice production minus total input costs (Table 2-14). Total cost, as we have seen, got high in Sawah and Semi-Sawah; however, Sawah and Semi-Sawah earn more total rice sell because of higher yield. Therefore net-income from Sawah (US\$981.5.9±449.7 ha^{-1}) is significantly higher than income from other four cropping system ($p<0.01$) (Table 2-15). Likewise, Semi-Sawah (US\$642.4±467.5 ha^{-1}) significantly earn more income than Gbaragi ($p<0.10$) and Baragi ($p<0.01$).

Table 2-11: Amount of Input of fertilizer[a] and herbicide

	n	NPK (kg/ha)	Urea (kg/ha)	Fertilizer (kg/ha)	Herbicide (litter/ha)
Sawah	29	203.4 (217.6)	62.9 (95.4)	266.3 (237.9)	2.8 (2.2)
Semi-Sawah	101	275.0 (371.9)	128.5 (256.4)	403.4 (429.6)	4.3 (3.8)
Gbaragi	140	92.2 (132.5)	58.8 (123.2)	151.0 (184.0)	3.3 (2.3)
Baragi	43	100.5 (182.6)	55.4 (105.0)	155.9 (218.6)	2.3 (1.8)
Naafena	6	568.4 (545.5)	34.3 (84.1)	602.7 (524.2)	2.1 (3.4)

[a] Fertilizer= NPK + Urea

The numbers in parentheses are standard deviations.

Table 2-12: Input cost of fertilizer and herbicide (US Dollar/ha)[a]

	n	Cost of NPK	Cost of Urea	Cost of Fertilizer*	Cost of herbicide
Sawah	29	95.4 (114.1)	29.9 (64.9)	125.3 (129.2)	13.1 (11.3)
Semi-Sawah	101	119.4 (158.5)	64.2 (139.1)	183.6 (211.3)	10.6 (10.9)
Gbaragi	140	39.0 (60.0)	27.7 (65.3)	66.7 (90.7)	16.5 (13.7)
Baragi	43	42.6 (74.4)	22.6 (54.9)	65.3 (97.8)	9.4 (10.3)
Naafena	6	340.6 (403.9)	17.6 (43.1)	358.2 (392.6)	1.4 (2.2)

[a] $1 = 116.91 Nigerian Naira

* Cost of Fertilizer=cost of NPK + cost of Urea

The numbers in parentheses are standard deviations.

Table 2-13: Input cost (US Dollar/ha) [a]

	n	Labor	Fertilizer	Herbicide	Power Tiller	Seed	Total
Sawah	29	255.4 (287.4)	125.3 (129.2)	13.1 (11.3)	29.6 (34.7)	N/A	423.5 (383.2)
Semi-Sawah	101	302.4 (249.4)	183.6 (211.3)	10.6 (10.9)	N/A	29.2 (53.4)	525.8 (373.6)
Gbaragi	140	148.0 (154.1)	66.7 (90.7)	16.5 (13.7)	N/A	12.5 (37.2)	243.6 (224.3)
Baragi	43	100.6 (82.1)	65.3 (97.8)	9.4 (10.3)	N/A	29.2 (65.7)	204.5 (171.6)
Naafena	6	253.5 (235.9)	358.2 (392.6)	1.4 (2.2)	N/A	15.2 (37.1)	628.3 (556.9)

[a] $1 = 116.91 Nigerian Naira

The numbers in parentheses are standard deviations.

Table 2-14: Income from rice cultivation (US Dollar/ha) [a]

	n	Rice sell[b]	Total cost	Income
Sawah	29	1405.0 (279.6)	423.5 (383.2)	981.5 (449.7)
Semi-Sawah	101	1168.2 (429.0)	525.8 (373.6)	642.4 (467.5)
Gbaragi	140	736.3 (361.9)	243.6 (224.3)	492.7 (315.9)
Baragi	43	579.3 (318.7)	204.5 (171.6)	374.8 (229.3)
Naafena	6	928.7 (396.6)	628.3 (556.9)	300.4 (340.2)

[a] \$1 = 116.91 Nigerian Naira

[b] One bag of rice is mean of each farmer. 34.1 US\$. This price is mean of price of rice bag from interview.

The numbers in parentheses are standard deviations.

Table 2-15: Difference of average yield between each cropping system (kg/ha)

	Naafena	Baragi	Gbaragi	Semi-Sawah
Sawah	681.1***	606.7***	488.8***	339.1***
Semi-Sawah	342.0	267.6***	149.7*	
Gbaragi	192.3	117.9		
Baragi	74.4			

*=p<0.10 **=p<0.05 ***=p<0.01

2.4. Survey on Spatial Structure

The data of 319 plots were geo-referenced by GPS survey. The plots data is described as polygon shape in vector dataset which is a key difference from other approaches mentioned above. It is important to select correct shape unit, otherwise, linking household and GIS data is impossible (Staal et al., 2002). The approach employed in this paper is to integrate spatial data into econometric method; therefore administrative units or grid cells which are not individual economic agents are unsuitable for the unit observation. Polygon shape, on the other hand, is based on individual economic agents; therefore, it is appropriate to be used in micro-level spatial distribution as observation unit.

Each plot polygon includes the information which is listed below: name of cultivator, distance to cultivator village, plot size, and elevation. These polygons are linked with the results from interview via GIS; consequently, 319 plots carry not only GIS-derived information but also household information, such as cropping method, yield, and other characteristics of cultivator.

2.4.1. Spatial Distribution (GIS layers)

The figures 2-2 through 2-13 are spatial distribution of cropping system, yield, and elevation at four research areas: respectively five villages (Shabamaliki, Nassarafu, Emiworongi, Tswatagi, and Emitsu), Emitsundadan, Ejiti, and Amgbasa. The natural classification system was taken for sortation.

Since 228 plots out of 319 were identified around five villages, it is easy to see the distribution of cropping system (Figure 2-2). Sawah fields can be seen in the middle of area; however the number of Sawah plots is limited i.e. only 19 plots. Semi-Sawah plots, on the other hand, are located in the western part of area, whereas traditional method Gbaragi is concentrated in the eastern part. To explain distribution of cropping system, a comparison with elevation may be helpful. Figure 2-4 indicates that elevation is higher in the west and gradually decrease toward the east where the location is next to river Bako.

In the area of Emitsundadan, only two cropping systems are found: Semi-Sawah and Naafena (Figure 2-5). In Ejiti area, Sawah and Semi-Sawah fields can be found adjacent to village; respectively ten plots for Sawah and 16 plots for Semi-Sawah (Figure 2-8). Therefore distribution of plots by yield marks red color around the village. As figure 2-7 and 2-10 show, the altitude in these areas, Emitsundadan and Ejiti, are higher than other area. The farmers from Amgbasa only cultivated traditional method Gbaragi in lower elevation area (Figure 2-11 and 2-13).

2.4.2. Approximate Elevation and Landscape

In this section, the rate of slope is estimated by using GIS and establish GIS-derived variable to integrate into econometric analysis. To calculate the change of slope, the landscape of the area is necessary; however, the elevation maps, which are shown in below, only indicate average elevation by plot unit. Therefore it is needed to define more detail information about landscape.

First, in order to examine the approximate landscape, vector dataset of elevation is changed to raster dataset and use neighborhood statistics scheme to calculate approximate elevation. The approximate elevation around five villages, for example, is shown in Figure 2-14. The area colored as red is higher elevation area, whereas green indicates lower area. Second, this approximate elevation raster data is used to calculate the average percentage of slope (Figure 2-15). Finally, plots vector data is set up as scope of zonal statics to calculate average change of slope (Figure 2-16). The distribution of plots by slope rate is shown in Figure 2-17. Same steps were taken to estimate average slope rate for each plot in other areas. The result of slope rate is set up as variable for econometric analysis.

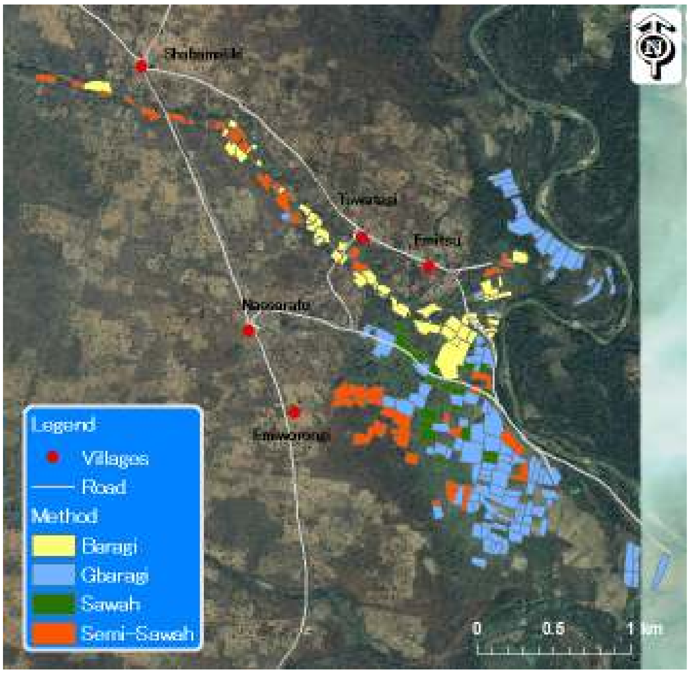


Figure: 2-3: Distribution of cropping method around 5 villages

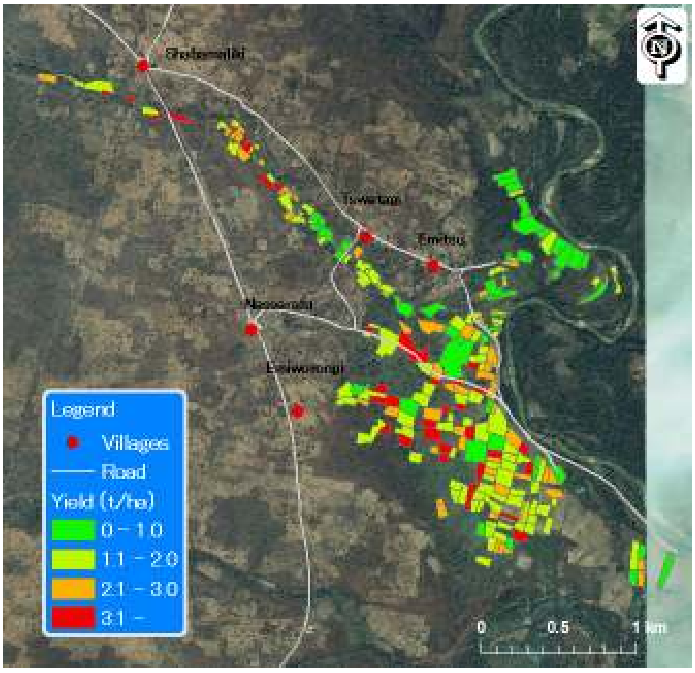


Figure 2-4: Distribution of yield around 5 villages

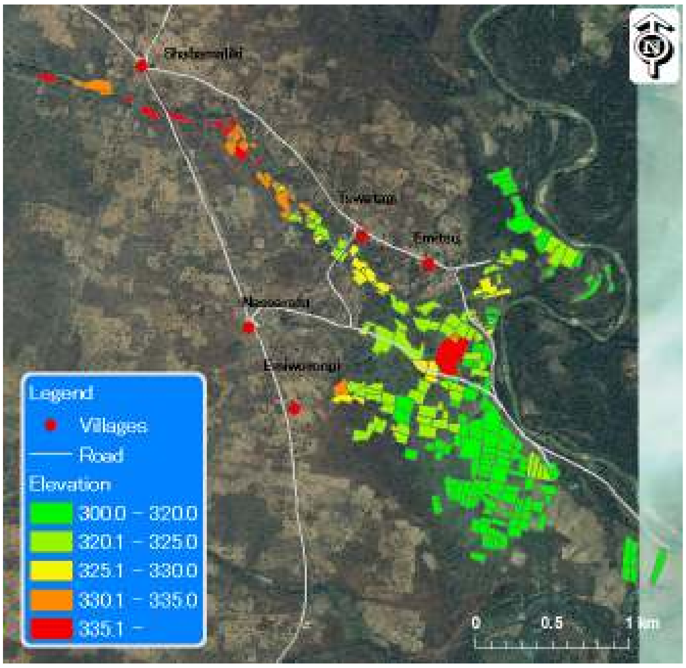


Figure: 2-5: Distribution of average elevation around 5 villages

Figure 2-6: Distribution of cropping method around Emitsundadan

Note: Source of background image is Google Earth

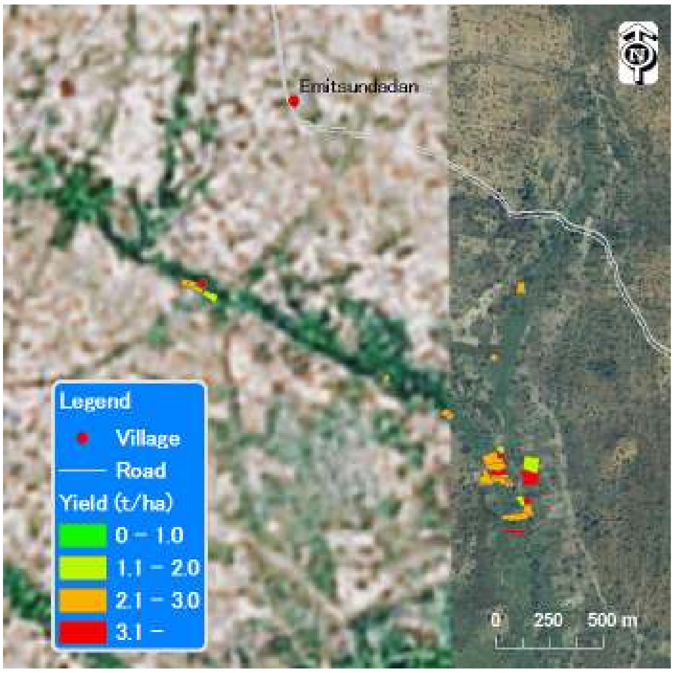


Figure: 2-7: Distribution of yield around Emitsundadan

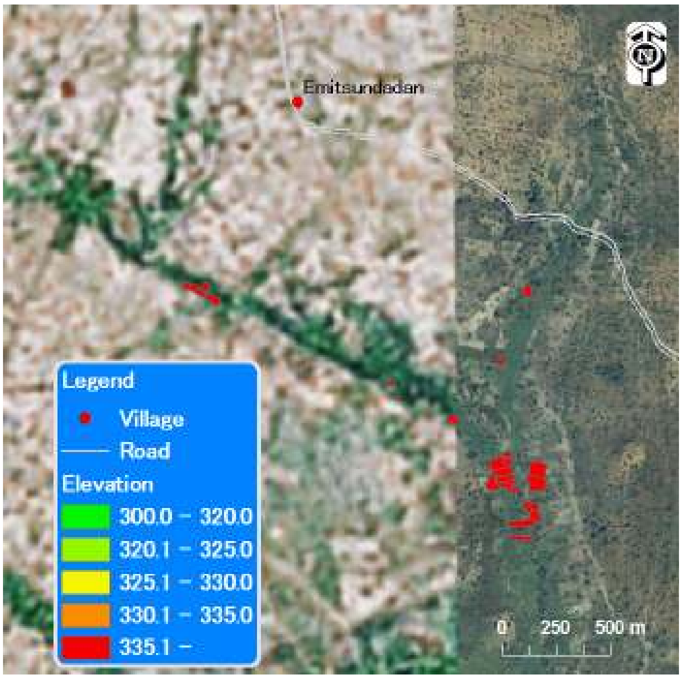


Figure 2-8: Distribution of average elevation around Emitsundadan

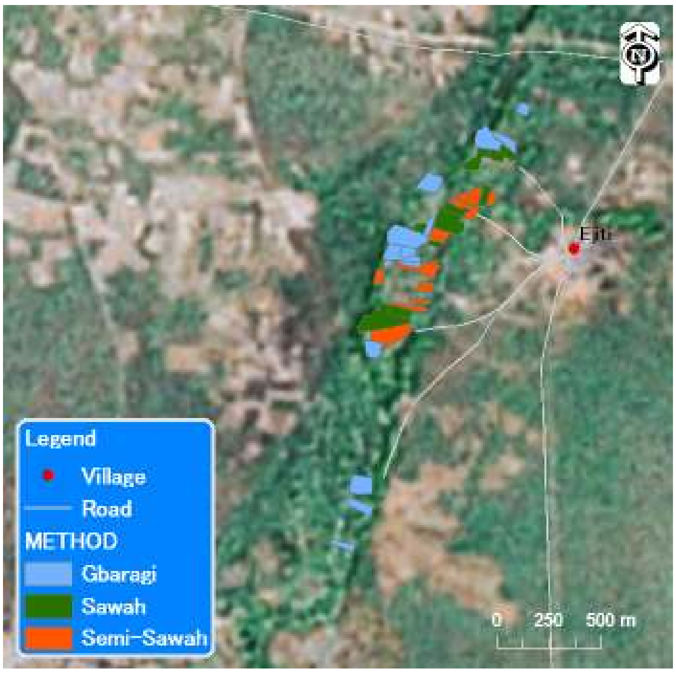


Figure: 2-9: Distribution of cropping method around Ejiti

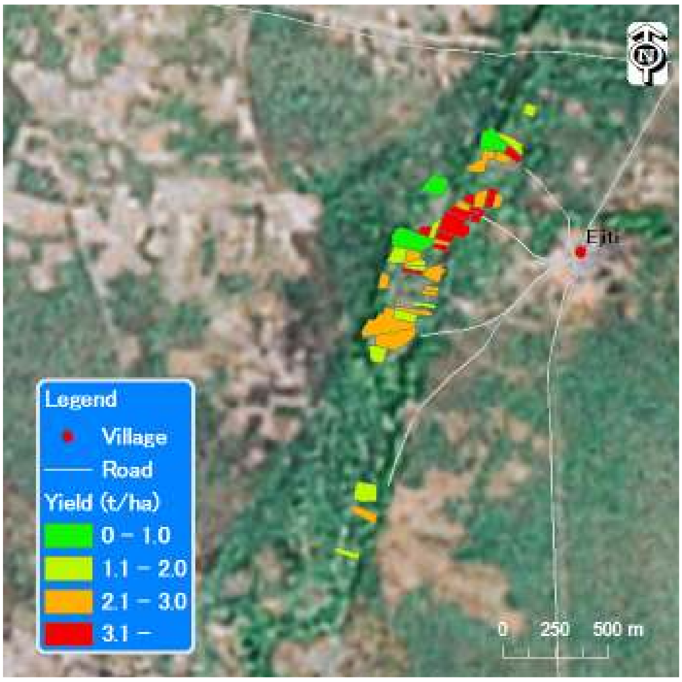


Figure 2-10: Distribution of yield around Ejiti

Note: Source of background image is Google Earth

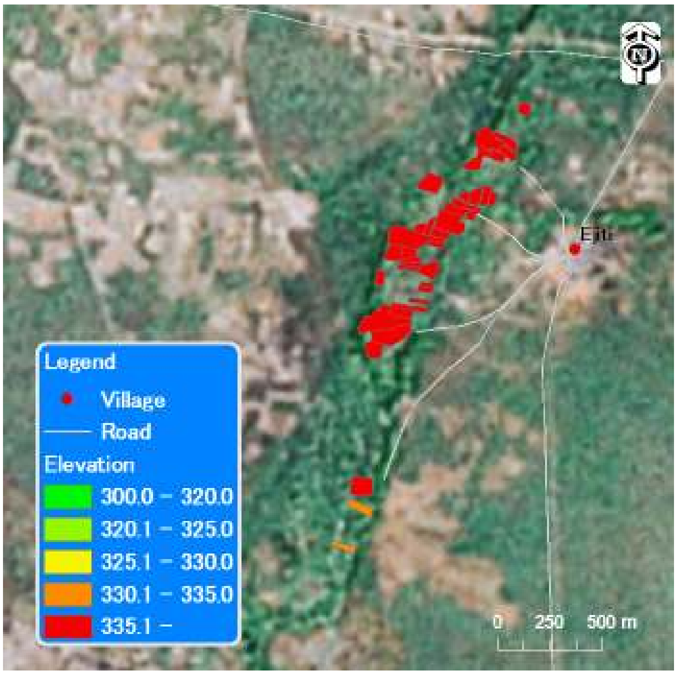


Figure: 2-11: Distribution of average elevation around Ejiti

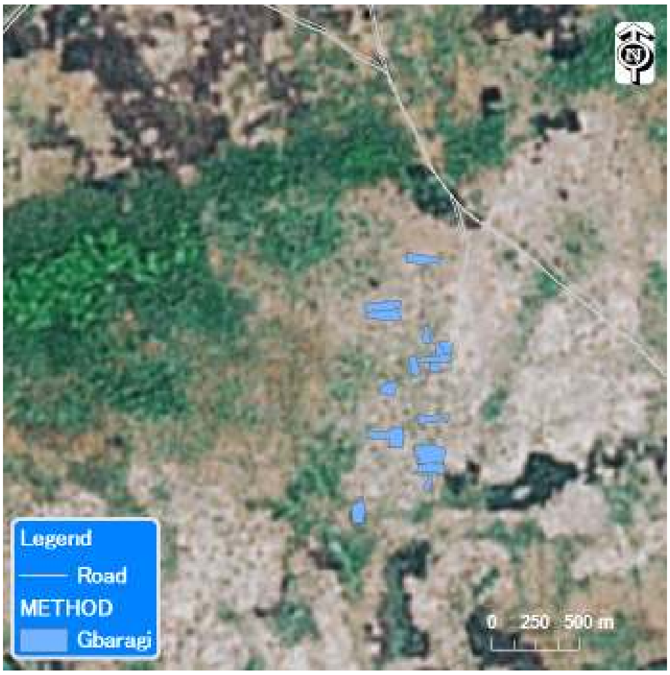


Figure 2-12: Distribution of cropping method for Amgbasa

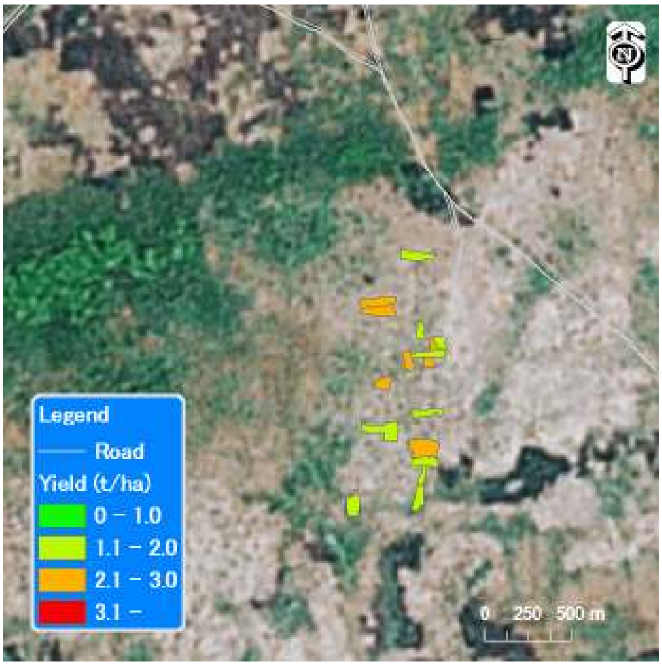


Figure: 2-13: Distribution of yield for Amgbasa

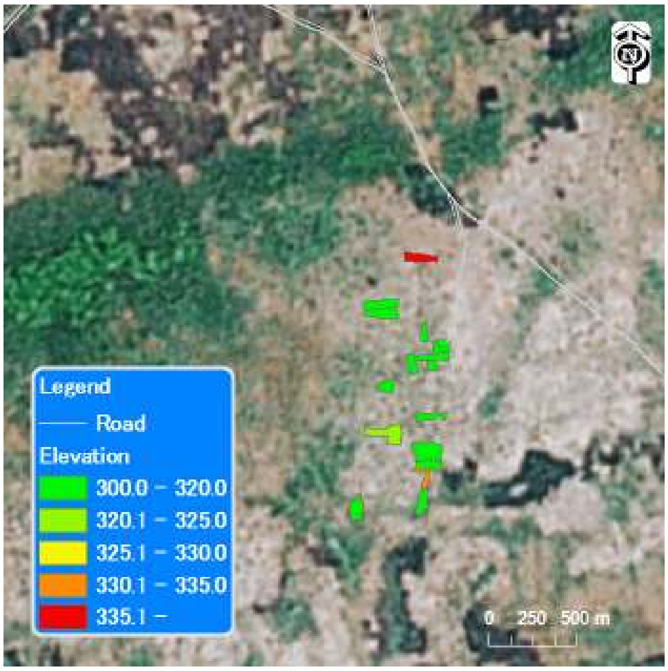


Figure 2-14: Distribution of average elevation for Amgbasa

Note: Source of background image is Google Earth

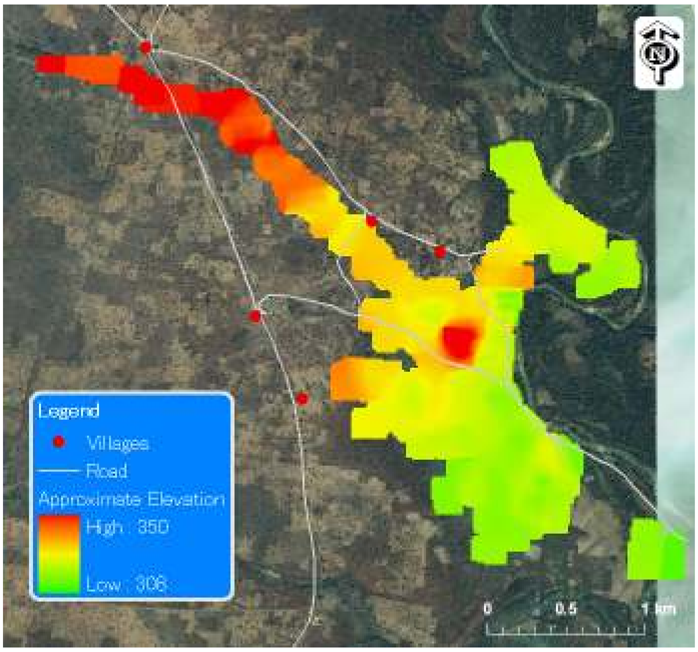


Figure: 2-15: Approximate elevation (Raster)

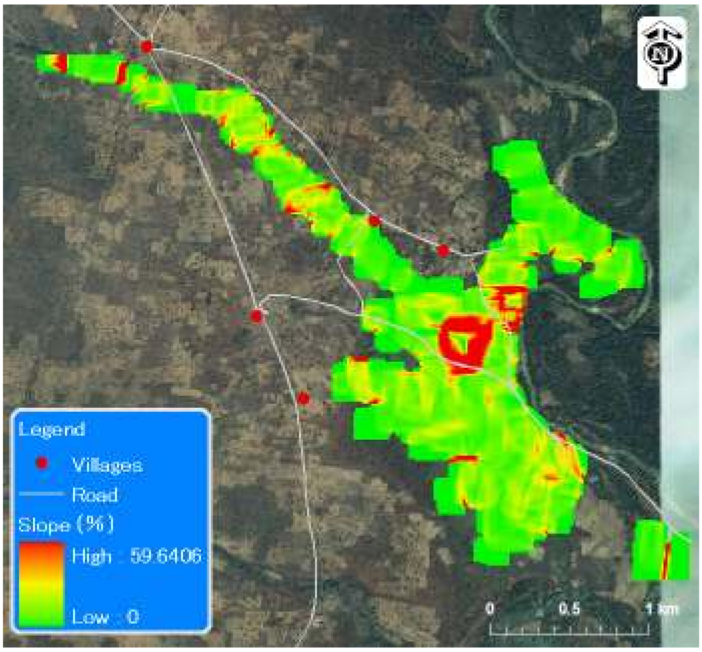


Figure 2-16: Percent of slope (Raster)

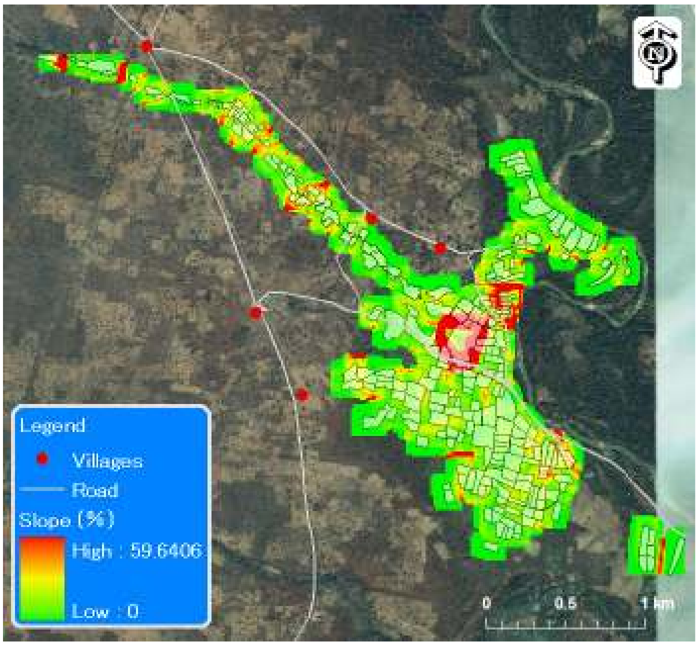


Figure: 2-17: Zonal statistics

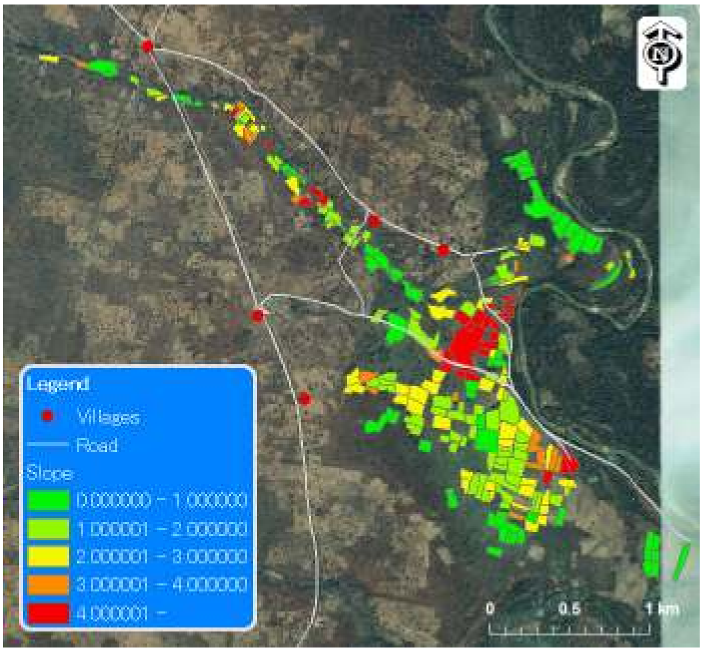


Figure 2-18: Distribution of plots by average slope rate

Note: Source of background image is Google Earth

2.5. Survey on Wealth Ranking and Expense

2.5.1. Use of Power Tiller and Wealth Ranking Survey

Using power tiller is necessary condition to cultivate Sawah rice fields and three villages (Shabamaliki, Nassarafu, and Ejiti) out of four participated villages own power tiller as community property. However, farmers who used power tiller in the season of 2008 are limited: respectively none for Shabamaliki, 14 farmers for Nassarafu, and seven for Ejiti (Table 2-16). As it has seen in Table 2-17, the main reason for not using power tiller in Shabamaliki is that water dosage around this area was too much to operate power tiller. In the case of Ejiti, only seven farmers could operate power tiller and rest of others could not use because the timing was competed against each other.

To identify the characteristic of power tiller users, wealth ranking survey was done referred from Sato (2002) in Ejiti village, for instance. One farmer who led Sawah project in the village was asked to rank all the household heads into five levels based on wealth. To avoid confusion of names, all household heads' faces were confirmed by digital camera. After classify all names, he was asked about the criteria he used to identify differences in economic condition. According to his wealth ranking, two people, one is ranked in middle class and the other was in bottom class, were randomly chosen to work on wealth ranking as same step as mentioned above.

The results of wealth ranking and number of power tiller users are shown in Table 2-18. Economic criteria which were often mentioned by farmers included: number of family labor, total cultivated area, non-farm work, and religious influence. This wealth ranking survey revealed that power tiller users were ranked in one or two class and no one ranked three and under did not; therefore power tiller was owned as community property, yet economically wealthy farmers used it preferentially.

Table 2-16: Number of power tiller users in three villages

	Interviewed household	User	Non-User
Shabamaliki	24	N.A.	24
Nassarafu	19	14	5
Ejiti	24	7	17

Table 2-17: Reasons of not using power tiller

	Too much water	Comepete against other farmer	Broke down	Capital shortage	Did not want to use
Shabamaliki	22				2
Nassarafu			5		
Ejiti		13	2	1	1

Table 2-18: Wealth Rank, number of power tiller users, and their Typical Characteristic in Ejiti

Rank		Power tiller User	Family labor	total cultivated area	Non-farm job	Religious influence
1	(n=3, 12%)	3	◎	◎	○	○
2	(n=7, 27%)	4	○	○	○	×
3	(n=9, 35%)	0	○	△	○	×
4	(n=2, 7%)	0	○	△	○	×
5	(n=5, 19%)	0	×	×	×	×

Note: ◎= strongly large, ○= large / yes, △= medium, ×= small / no

2.5.2. Expense for Religious Ceremony

Wealth ranking reveals that religious influence is one of the important indexes for local farmers. Since all farmers are committed to Islam, famers are celebrating Islamic ceremony, locally called "Sara", after fasting period which was held in 29th of September in the year of 2008. Everyone dresses up with new clothes for celebration and female and children gather to sing songs. Most importantly, people offer up livestock as sacrifice to Allah. There is an order for sacrifice which male sheep is most precious sacrifice, followed by male goat, female sheep, and female goat. Sacrificed livestock among farmer group is listed in Table 2-19. More than half percent of farmers from Sawah farmer group sacrificed male sheep to God, whereas other farmers from two groups chose either male sheep or male goat. The order of sacrificed is reflected the price (Table 2-20). Some farmers offered up their own livestock as sacrifice; therefore, the price for own livestock is calculated by average price from same kind of sacrificed livestock. As expected, price for male sheep, which is most precious sacrifice, is higher than other livestock. Table 2-21 indicates the average expenses for new clothes and sacrifice, as well as total expense which is sum of expenses of clothes and sacrifice. It is clear that Sawah farmers spend more money on religious ceremony, which consists with result of wealth ranking.

Table 2-19: Sacrificed livestock

	n	Male Sheep	Male Goat	Female Sheep	Female Goat	No sacrifice
Sawah farmer	21	15 (71%)	4 (19%)	1 (5%)	1 (5%)	0 (0%)
Semi-Sawah farmer	80	30 (37%)	35 (44%)	2 (3%)	10 (12%)	3 (4%)
Traditional farmer	31	13 (42%)	13 (42%)	1 (3%)	4 (13%)	0 (0%)

Table 2-20: Average price of sacrificed livestock (US$/household)

	n	Male Sheep	Male Goat	Female Sheep	Female Goat	No sacrifice
Sawah farmer	21	99.9 (45.6)	43.3 (4.9)	68.4	46.7	0
Semi-Sawah farmer	80	79.5 (27.8)	47.7 (9.0)	68.4 (0.0)	47.5 (8.4)	0
Traditional farmer	31	81.8 (19.7)	41.4 (6.6)	68.4	44.8 (14.2)	0

The numbers in parentheses are standard deviations.

Table 2-21: Average expenses for religious ceremony (US$/household)

	n	Expense for new clothes	Expense for sacrifice	Total expense for ceremony
Sawah farmer	21	115.0 (58.5)	85.1 (45.4)	200.1 (90.7)
Semi-Sawah farmer	80	90.8 (55.2)	58.3 (26.3)	149.0 (71.2)
Traditional farmer	31	75.0 (40.5)	59.7 (24.1)	134.7 (55.4)

The numbers in parentheses are standard deviations.

Chapter 3:
Econometric Analysis

Children with smiling faces.

(Photograph is taken in Nassrafu, 09/01/2008)

3.1. Working Hypotheses

As mentioned above, three theoretical hypotheses are set up for this study. To test the theoretical hypotheses, eight working hypotheses (hypotheses) are speculated.

Hypothesis (1) "*Increment of economical factors induces adoption of Sawah technology.*"

The wealth ranking from Ejiti village shown in Table 2-18 reveals that there are several common economic characteristics among power tiller users: the number of family labor, total cultivated area, and religious influence. Since only farmers who use power tiller can cultivate Sawah, these characteristics could be the determining factors of adoption of Sawah technology. Therefore, with respect to adoption of Sawah technology, the following hypotheses are postulated: **hypothesis 1.1**: large number of family members induces adoption because of their labor availability; **hypothesis 1.2:** the adopting probability increases in proportion to increasing the size of the total area of cultivated paddy field; and **Hypothesis 1.3:** the cultivators who spend more money on religious ceremony adopt Sawah.

Parameter of non-farm work is omitted because there is no big difference between each ranking. Instead of non-farm work, the number of livestock is preferable indicators for economic characteristics since there are differences in the number of livestock and share of livestock income (see table 2-6) even though many farmers possess them. Hence I stated last hypothesis which is followed: **hypothesis 1.4:** the number of livestock has positive effects on the adopting probability of Sawah.

Hypothesis (2) "*Farmers copy the essence of Sawah technology and innovate it to suitable cropping system.*"

Farmers who cannot adopt Sawah technology copy the essence of Sawah and innovate it to suitable cropping system which is referred as "Semi-Sawah". Since Sawah farmers are economically rich is one of hypothesis of this study, the determining adoption of Semi-Sawah have no relation with economical factors or relatively poor farmers adopt Semi-Sawah. Therefore, **hypothesis 2.1** is that the size of total cultivated paddy field has a negative effect on adoption of Semi-Sawah technology. Semi-Sawah, at the same time, demands more labor than other methods;

Semi-Sawah is expected to be suitable for small scale paddy fields. Thus, **Hypothesis 2.2** is that the individual plot size affects negatively on adoption of Semi-Sawah.

Farmers innovate Semi-Sawah technology so that they can easily adopt technology; however, most of them still continue cultivating traditional cropping system. One of the reasons could be that farmers make a selective decision on adopting Semi-Sawah by considering the plot conditions. Therefore, **hypothesis 2.3** is that adoption of Semi-Sawah technology depends on the plot characteristics.

Hypothesis (3) "*Farmers benefit from Sawah technology.*"

In order to define the benefit for farmers, it is important to test the effort of Sawah technology on rice yield and income. Insistence of this study is that Sawah technology effects positively on both yield and income, even considering with other factors. Therefore, **hypothesis 3.1** is that Sawah technology positively affects the rice yield and income.

3.2. Estimation Method

3.2.1. Multinomial Logit Model and Tobit Model

The adoption factors of three technologies which are likely to have an effect on rice yield are examined, i.e. Sawah, Semi-Sawah, and total use of fertilizer.

Multinomial Logit model is used to estimate the adoption rate of Sawah and Semi-Sawah. Probit model is commonly used to define the characteristics of newly introduced technologies. For example, Sakurai (2002) analyzed the characteristics of farmers that adopted irrigation canal and modern varieties in Ghana, and Kijima et al. (2008) assessed the characteristics of farmers who adopted the new rice variety, NERICA, in Uganda. However, Multinomial Logit model is appropriate for this study because farmers are facing with three options: Sawah, Semi-Sawah, or traditional.

Three sets of variables are used as independent variables: cultivators' characteristics, household economics (assets, other source of income, and expenses), and plot characteristics.

First, since adoption of technology depends on each farmer's decision, characteristics of cultivators might be an important variable. Cultivators' characteristics include age, formal education years of heads, number of family member and the proportion of both male and female adults, and total area of cultivated paddy fields, as well as the distance to the closest market.

Second, it was explained in the preceding chapter that to cultivate Sawah and Semi-Sawah called for more input compared to traditional cropping system; therefore variables of assets and other source of income are added as independent variables. Livestock that farmers own as assets are grouped into two depending on their size and are added as variables: chicken, ducks, and pigeons are grouped as small size livestock and cattle, sheep and goats as large size. Other sources of income include income from livestock, off-season crop, and non-farm work. In addition to this, total expense for the religious ceremony and the cost of livestock used for sacrifice to Allah are used as independent variables.

Finally, plot condition is also an essential factor for technology adoption and is included in the equation. Plot characteristics include environmental variables (i.e. elevation and rate of slope calculated in chapter 2), plot size, and the distance to cultivators' village as independent variables.

The Multinomial Logit model is specified as follow:

$$\Pr ob(S_i = j) = \frac{\exp(\gamma'_j x_i + \delta'_j y_i + \lambda'_j z_i)}{1 + \sum_{j=1}^{2} \exp(\gamma'_j x_i + \delta'_j y_i + \lambda'_j z_i)} \quad (1)$$

where S_i represents the cropping system that plot i is engaged in: Sawah (j=2), Semi-Sawah (j=1), or traditional (j=0). I assume γ'_0=0, δ'_0=0, *and* λ'_0=0 for normalization.

Vector x_i stands for a set of variables of cultivators' characteristics for plot i, vector y_i represents a set of variables relating to household economics, and z_i is a set of variables of plot characteristics.

Multinomial Logit model can identify that the factors affect whether positively or negatively; however, its coefficient has almost no meaning. Therefore, the marginal effects are estimated to clear up specific magnitude toward the adoption of technologies.

Another regression formula is set up to explain the use of chemical fertilizer which is an endogenous variable affecting the yield. Total weight (kg) of NPK and urea used per hectare is used as the dependent variable and the same parameters used in the equation (1), as independent variables. Because fertilizers are not applied at one third of plots, the Tobit model is used for estimation. More specifically, the probability that plot i is applied fertilizer is assumed to be given by:

$$F_i^* = \beta_0 + \beta x_i + u_i,\ \mathrm{u}_i | x \sim Normal\ (0, \sigma^2) \tag{2}$$

$$F_i = \begin{cases} F_i^* & if\ F_i^* > 0 \\ 0 & if\ F_i^* \leq 0 \end{cases} \tag{3}$$

where F_i^* is a latent variable. Equation (3) implies that the observed variable, F, equals F^* when F^* > 0, but $F = 0$ when $F^* \leq 0$.

3.2.2. Two-Stage Least Squares model

In the previous section, explanatory formula for the adoption of three technologies was mentioned. In this section, I employ Two-Stage Least Squares model, well known as 2SLS, to evaluate the impact from three technologies on rice yield and profit.

Two regression expressions are made, i.e. rice yield (kg) per hectare as dependent variable, and net-income (US$), which includes self-expenses for labor per hectare. The first stage of 2SLS is Multinomial Logit estimation and Tobit estimation which are stated last section. The second stage of 2SLS is that I use predicted probabilities of adopting Sawah and Semi-Sawah and of use of fertilizer which are estimated in the first stage as instrumental variables. For other independent variables, selected variables from the equation (1) which conceivably have an effect on rice yield and income are chosen.

Accordingly, the following equation is postulated as second stage:

$$y_i = \beta_0 + \beta_1 Tech_i + \beta_2 X_i + \nu_i \tag{4}$$

where y_i is the yield or net-income from plot i and $Tech$ is instrumental variable. X is sets of selected variables.

3.3. Estimation Results

3.3.1. Determinants of Sawah and Semi-Sawah

The regression results for the Sawah and Semi-Sawah adoption function, as well as the use of fertilizer are provided in Table 3-1. Column (1) and (2) are results for the probability of Sawah and Semi-Sawah adoption using Multinomial Logit model, whereas column (3) indicates use of fertilizer estimated by the Tobit model.

With respect to verify hypothesis (1), the ratio for the number of household members has a significantly positive effect on adoption of Sawah. This result indicates that households with more family labor are inclined to adopt Sawah. Therefore, hypothesis 1.1 is supported. The size of total paddy field also has a positive effect on adoption, as expected, thus, hypothesis 1.2 is supported.

In respect of variables concerning the total expense for the religious ceremony, the result shows a significant and positive effect. This result may indicate that religious empowered farmers more likely to adopt Sawah technology. Thus, hypothesis 1.3 is supported. The number of small livestock possessed by each farmer has a significantly positive effect, whereas it is not the case with large livestock. These results are unexpected; however, the hypothesis 1.4 is supported. Working hypotheses 1.1 through 1.4 are supported; hence theoretical hypothesis (1) is supported.

Regarding hypothesis (2), the size of total paddy field and individual plots insist a negative and significant effect on adoption of Semi-Sawah. This result admits of two interpretations. One is that Semi-Sawah is preferred to be cultivated at small plot and the other is that small scale farmers or relatively poor farmers are more likely to adopt Semi-Sawah technology. Hereby hypothesis 2.1 and 2.2 are supported. Almost every explanatory variable of cultivators' characteristics and household economics has no significant effect on Semi-Sawah adoption, which is expected. Since Semi-Sawah is innovated to easily adoptable technology by farmers, conditions of farmer have no effect on adopting technology. In contrast to weak impact from two sets of variable, plot characteristics affect strongly. Plot size and distance to plot have a significant negative effect. The reason of negative effect from plot size is already explained in above. The negative effect from distance to plot can be explained by that farmers more likely to adopt new technology close to their dwellings so that they can take good care. This is irrelevant to hypothesis (2) but distance to plot affects negatively on adoption of Sawah as same reason. Elevation has a positive effect significantly.

This is, because water dosage is too large in lower elevation area. The marginal effects of three variables are large: respectively -0.226, -0.189, and 0.006. Hence, hypothesis 2.3 is supported. For the above results, I conclude hypothesis (2) is supported.

There are more important findings in the results of the determinant of the technology adoption (i.e. Sawah and Semi-Sawah).

First, the distance to closest market from the cultivators' village has a negative effect on Sawah adoption, whereas it effects positively on Semi-Sawah adoption. This can be explained that since Sawah technology is diffused via a NGO, WIN, the villages which are close to towns are more likely to be selected as an operation site; therefore the distance to the closest market effects negatively on Sawah adoption. On the other hand, Semi-Sawah is diffused widely, thus market variable shows positive effect on Semi-Sawah adoption.

Second, the determinants of the use of fertilizer, which is shown in Column (3), have several common results with determinants of Sawah and Semi-Sawah. Formal education level and expenses for religious ceremony have a positive effect on adoption of Sawah and the use of fertilizer, significantly. Positive effect from education can admit two interpretations: farmers adopt technologies of Sawah and fertilizer because they are educated or relatively high-educated farmers and are economically rich enough to adopt them. On the other hand, positive effect from the expense for religious ceremony can be explained that religiously empowered farmers have ample purchasing power for fertilizer. As for Semi-Sawah, the size of the total paddy field and plot size affect negatively on the use of fertilizer: -92.976 at significance level of one percent for the total size and -129.051 at significance level of ten percent for the plot size, respectively. The most likely explanation is that farmers can not apply fertilizer which is adequate for the total size of the paddy field due to their credit constraint.

Third, several determinants are found in the variables of plot characteristic. The slope rate has a strong and positive effect on Sawah adoption whose ratio is 0.204 at significance level of one percent. This might be explained by the location where Sawah is adopted. Distribution of average elevation, as been shown before, indicates that paddy fields of Semi-Sawah and traditional method Gbaragi are cultivated in higher and lower areas around the five villages, respectively (See Figure 2-2 and 2-4); therefore Sawah plots might be adopted in the inner areas where slope rate is high but elevation is not as high as areas where Semi-Sawah is adopted. This is within imagination; however, elevation has no significant effect on adoption of Sawah, whereas it has a positive effect on Semi-Sawah, which endorses the conclusion of the study Elevation also has a positive effect on the use of fertilizer. This positive effect of elevation might be because higher elevation areas are more unfertile than lower areas, thus farmers apply more fertilizers. However, it is incompetent to discuss this issue.

Table 3-1: Determinants of Sawah, Semi-Sawah and use of fertilizer at plot level

	Multinomial Logit				Tobit	
	Sawah		Semi-Sawah		Fertilizer (kg/ha)	
	(1)		(2)		(3)	
Constant	5.207		-2.909		-598.444	**
	(0.70)		(-1.25)		(-1.99)	
Cultivators' characteristics						
Head's age	0.054	*	0.006		-2.164	
	(1.73)		(0.30)		(-0.88)	
	[0.001]		[0.001]			
Head's years of formal education	0.168	**	-0.038		18.176	***
	(2.24)		(-0.85)		(3.01)	
	[0.002]		[-0.006]			
Number of household members	0.058	*	0.004		1.709	
	(1.72)		(0.14)		(0.58)	
	[0.001]		[0.000]			
Proportion of male adults aged 15-60 (%)	-0.032		0.008		4.406	**
	(-1.05)		(0.49)		(2.02)	
	[0.000]		[0.001]			
Proportion of female adults aged 15-60 (%)	0.076	*	-0.009		-2.859	
	(1.91)		(-0.48)		(-1.15)	
	[0.001]		[-0.002]			
Size of total paddy field (ha)	0.822	*	-0.507	**	-92.976	***
	(1.70)		(-2.14)		(-2.89)	
	[0.011]		[-0.080]			
Distance to closest market from village(km)	-0.968	***	0.095		16.839	
	(-3.64)		(0.91)		(1.21)	
	[-0.012]		[0.017]			
Household economics						
Number of small livestock	0.079	***	0.006		-1.831	
	(3.10)		(0.46)		(-1.08)	
	[0.001]		[0.001]			
Number of large livestock	-0.038		0.020		6.146	
	(-0.72)		(0.61)		(1.38)	
	[0.000]		[0.003]			
Income from livestock (US$)	0.001		-0.001		0.054	
	(1.46)		(-0.96)		(0.79)	
	[0.000]		[0.000]			

Table 3- :(Continued)						
	(1)		(2)		(3)	
Income from off-season crop (US$)	0.000		0.001		0.357	**
	(0.09)		(1.19)		(2.04)	
	[0.000]		[0.000]			
Income from non-farm work (US$)	0.000		0.000		0.026	
	(1.50)		(0.07)		(1.43)	
	[0.000]		[0.000]			
Expense for religious ceremony (US$)	0.010	*	0.003		1.339	***
	(1.68)		(0.88)		(2.60)	
	[0.000]		[0.001]			
Cost of sacrifice for religious ceremony	-0.005		0.001		0.644	
(US$)	(-0.67)		(0.23)		(1.01)	
	[0.000]		[0.000]			
Plot characteristics						
Plot size (ha)	-0.722		-1.474	**	-129.051	*
	(-0.97)		(-2.22)		(-1.95)	
	[-0.005]		[-0.226]			
Distance to plot (km)	-1.836	***	-1.250	***	7.659	
	(-3.22)		(-4.40)		(0.47)	
	[-0.019]		[-0.189]			
Elevation	-0.049		0.039	**	5.198	***
	(-0.80)		(2.52)		(2.94)	
	[-0.001]		[0.006]			
Slope rate (%)	0.414	***	-0.001		5.723	
	(3.17)		(-0.01)		(0.60)	
	[0.005]		[-0.001]			
Number of observations	319				319	
Pseudo R^2	0.35				N/A	

Note: Absolute value of z or t-statistics are in parentheses, while those in brackets represent marginal effects at the average.

*=p<0.10 **=p<0.05 ***=p<0.01

3.3.2. Determinants of Rice Yield and Income

Finally, the effects of Sawah and Semi-Sawah on rice yield and income (including self-expenses for labor) are examined. Predicted variables of the three technologies, as mentioned above, are used as instrumental variables. To simply confirm the impact of Sawah and Semi-Sawah on yield and income, two equations without the instrumental variable of fertilizer is added. The results are shown in Table 3-2 and 3-3. Column (1) and (3) employ three instrumental variables together and the remaining columns employ two technological variable (i.e. Sawah and Semi-Sawah).

The result is very clear that all three technologies contribute to the increase of rice yield. Especially, adoption of Sawah technology affects more greatly whose coefficient is 1.1 t ha^{-1}, whereas it is 0.7 t ha^{-1} for Semi-Sawah. Judging from the coefficience, an addition of one extra fertilizer (kg) increases the rice yield by 1.2 kg ha^{-1}.

There are several important findings on rice yield. First, the age of the household head has a significantly positive effect upon the increase of rice yield ($p<0.05$). One may assume that elder farmer produces more yield than younger farmers because of their longtime farming experiences. Second, the number of household members has an effect on rice yield. Third, rice yield increases as the distance to the closest market from the village and plot size decreases. The negative significant sign for the distance to market explains that farmers whose residences are close to the market are more likely to adopt Sawah technology, as it is shown above, thus, plots closer to the residence yielded more rice than others. The effect of plot size indicates that an increase of one hectare of field decreases the yield by 406 kg ha^{-1}, which is explained by the poor capacity of farming. Finally, number of total livestock affects positively against the yield.

As for the income from rice, the income function shows that the adoption of Sawah enhances rice income as indicated by the positive, significant sign for the predicted probability of Sawah adoption. But the adoption of Semi-Sawah and the use of fertilizer have no significant effect on the income. The input cost might be the reason for non-significant effect on income from Semi-Sawah. Semi-Sawah technology induces increment of rice yield, yet it also calls more cost of labor and fertilizer (see Table 2-10). The non-significant effect on rice income from use of fertilizer can be explained by that large amount of fertilizer was used for the plots of Naafena; however, the income from Naafena is less than other cropping system (see Table 2-11 and 2-14).

Other variables significantly consist with the results for rice yield, except the number of total livestock, which has no significant effect on the rice income, and proportion of female adults. It is shown that the proportion of female constituent has a negative effect on rice income. This can be explained by the fact that farm activity related to income only depends on male labor.

These results, therefore, lead to the conclusion that technological variables increase rice yield greatly, though, only Sawah technology out of three technologies triggers an increment of rice income. Hence theoretical hypothesis (3) is supported. It is, however, noteworthy that the R squared for the estimation result for income is only 0.28, whereas yield is 0.60. Further study to identify the strong effective factor on income is necessary.

Table 3-2: Estimation results of rice yield and net-income functions (2SLS)

	Yield (kg/ha)		Yield (kg/ha)		Income (US$/ha)		Income (US$/ha)	
	(1)		(2)		(3)		(4)	
Constant	2,041.256	***	2,217.683	***	1,311.056	***	1,306.660	***
	(6.74)		(6.55)		(7.77)		(7.70)	
Instrumental variable								
Adoption of Sawah	1,125.350	***	1,213.197	***	269.716	**	267.527	**
	(4.96)		(4.84)		(2.14)		(2.13)	
Adoption of Semi-Sawah	669.488	***	1,121.432	***	-90.398		-101.660	
	(3.65)		(6.17)		(-0.88)		(-1.11)	
Use of fertilizer (kg/ha)	1.197	***			-0.030			
	(7.52)				(-0.34)			
Household and plot characteristics								
Head's age	9.299	**	7.163	*	6.037	***	6.090	***
	(2.35)		(1.63)		(2.74)		(2.76)	
Head's years of formal education	3.646		20.085	*	1.607		1.197	
	(0.36)		(1.84)		(0.29)		(0.22)	
Number of household members	11.666	***	15.432	***	6.617	***	6.523	***
	(2.85)		(3.40)		(2.90)		(2.86)	
Proportion of male adults aged 15-60 (%)	-3.494		1.654		-2.028		-2.157	
	(-1.02)		(0.44)		(-1.06)		(-1.14)	
Proportion of female adults aged 15-60 (%)	-5.463		-7.061	*	-5.831	***	-5.792	***
	(-1.47)		(-1.70)		(-2.81)		(-2.78)	
Distance to market from village (km)	-79.457	***	-89.386	***	-70.202	***	-69.954	***
	(-4.69)		(-4.74)		(-7.45)		(-7.39)	
Number of total livestock	8.541	***	9.916	***	0.743		0.708	
	(3.80)		(3.98)		(0.59)		(0.57)	
Plot size (ha)	-406.204	***	-570.889	***	-198.060	***	-193.956	***
	(-3.79)		(-4.80)		(-3.32)		(-3.25)	
Number of observations	319		319		319		319	
R^2	0.60		0.50		0.28		0.27	

Note: Absolute value of t-statistics are in parentheses

*=p<0.10 **=p<0.05 ***=p<0.01

Chapter 4:
Application for Future Development

Picture of in the middle of cooking of Wild Rats which taste are sweet and good.

(Photograph is taken in Emitsundadan, 07/15/2009)

In the preceding chapter, I have examined the determining factors for local people to adopt two kinds of technology, Sawah and Semi-Sawah. Furthermore, I have analyzed how Sawah technology used for rice fields and its income positively impacted those people. In this chapter then, I will verify that Sawah technology will be diffused more widely and its research area will be developed further in the future. The argument is twofold: First, I will integrate the result of econometric analysis estimated in Chapter 3 into GIS to identify the plots which are highly suitable for Sawah technology. This investigation will possibly provide valuable information for future decision making for Sawah development. Second, I will estimate by loan simulation that Sawah technology might be diffused by farmers themselves rather than formal organizations, such as NGOs, in the future.

4.1. Spatial Predictions of Sawah Technology Uptake

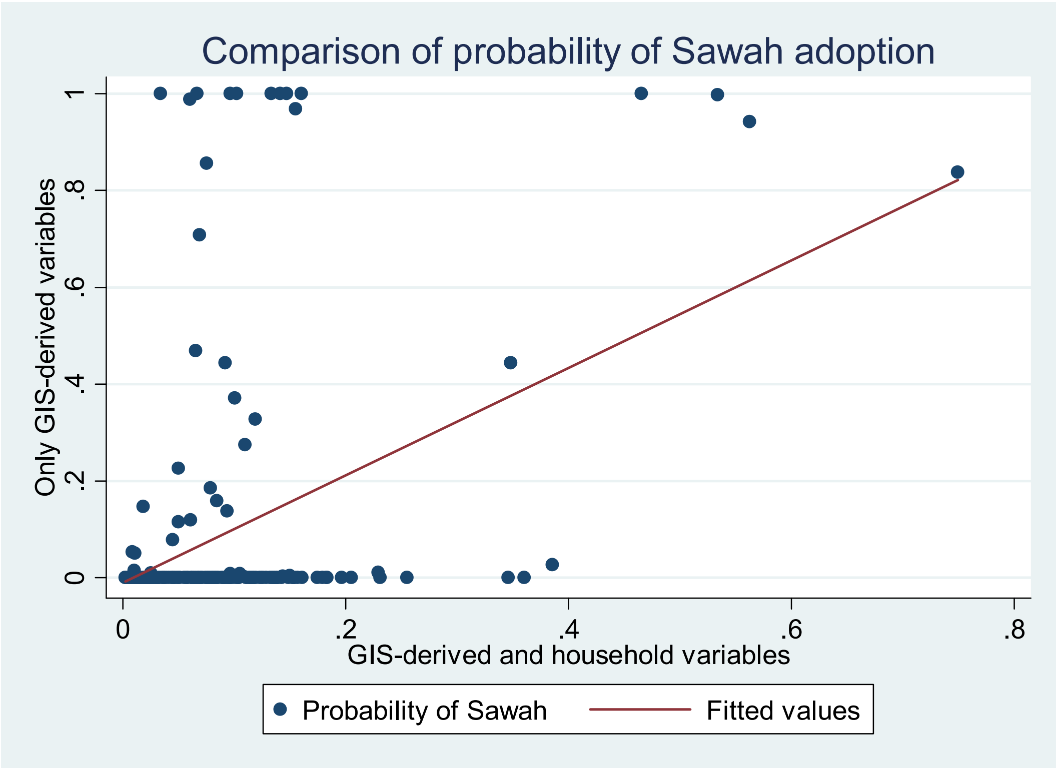
To facilitate diffusion of Sawah technology, plots that are potentially adaptable for Sawah are predicted by the methodology referred from Staal et al. (2002). Staal et al. use logistic regression model to estimate the prediction of probability of adopting agricultural technologies relating to stockbreeding. One of the key points in his study is that he draws a comparison between logistic formula with just GIS-derived variables and formula with not only GIS-derived, but also household characteristic variables.

In order to estimate adopting probabilities of Sawah and Semi-Sawah, I establish two Multinomial Logistic equations, i.e. the equations with only GIS-derived variables and equation with GIS-derived and household variables, using 228 plots data around five villages, for instance. For the GIS-derived variables, a distance to the River Bako which is flows from the north to the south in the east side of the area is calculated via GIS and added as a GIS-derived variable in addition to the same set of variables of plot characteristic in equation (1). For the equation with GIS-derived and household variables, the dependent variable and independent variables are almost the same as equation (1), except that the distance from the River Bako is added.

The results of predicted probability from two estimations are illustrated in the distribution graphs in Figure 4-1. As you can see clearly, the variance of probability of adopting Sawah is large, whereas the probability of adopting Semi-Sawah shows a good comparison with each other, which is not unexpected. One explanation for the no comparison of probability of adopting Sawah is that the factor determining whether to adopt Sawah by farmers is related with a ranking of wealth. Thus, high probability values using only GIS-derived variables become low probability if household variables are added. It is not hard to think that Pseudo R^2 for the equation using only GIS-derived variables is lower than the other, i.e. 0.14 for only GIS-derived variables and 0.74 for full set variables. For Semi-Sawah, Pseudo R^2 for the equation using only GIS-derived variables is 0.24, whereas 0.29 for equation using full set variables. In this way, we are able to illustrate the probability of uptake maps of the both results from both equations with only GIS-derived variables and with full set of variables. The important point to note is that the plots in figures are classified by quartile of predicted values of each technology. For example, the plot colored as green indicates "0 – 24 %" which means the predicted probability value of this plot is within the predicted probability value of 25^{th} percentile of actual Sawah or Semi-Sawah plots; therefore, it does not means the plot has 0 – 24 percent of probability.

Figures 4-2 and 4-3 show the predicted probability maps for Sawah adoption by using respectively GIS-derived variables and full set of variables respectively. Figure 4-2 indicates that many plots in the east side of the area, spatially, have high potential for adopting Sawah technology; however, potential plots are limited if household variables are included. This indicates an important point, that is, farmers who cultivate paddy plots in east side might be able to cultivate Sawah plots if they receive some kind of assistance to effect on their household characteristics.

Figures 4-4 and 4-5 shows predicted probability of Semi-Sawah adoption. Since probability values of two equations are comparable, two maps look similar. High potential Semi-Sawah plots are concentrated in the west side of area. Since Semi-Sawah is spilled over from Sawah technology imperfectly, Semi-Sawah technology supposedly diffuses gradually from highly potential area in the figures.



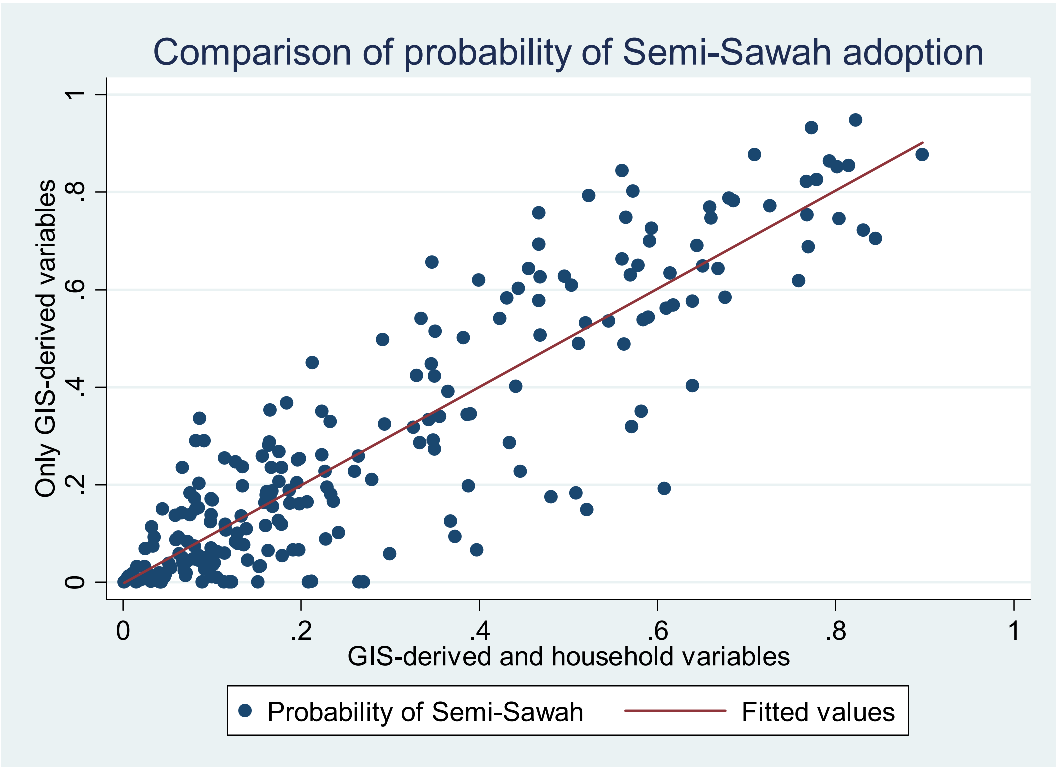


Figure 4-1: Comparison of predicted probability of adopting Sawah and Semi-Sawah between full set of independent variables and only GIS-derived variables

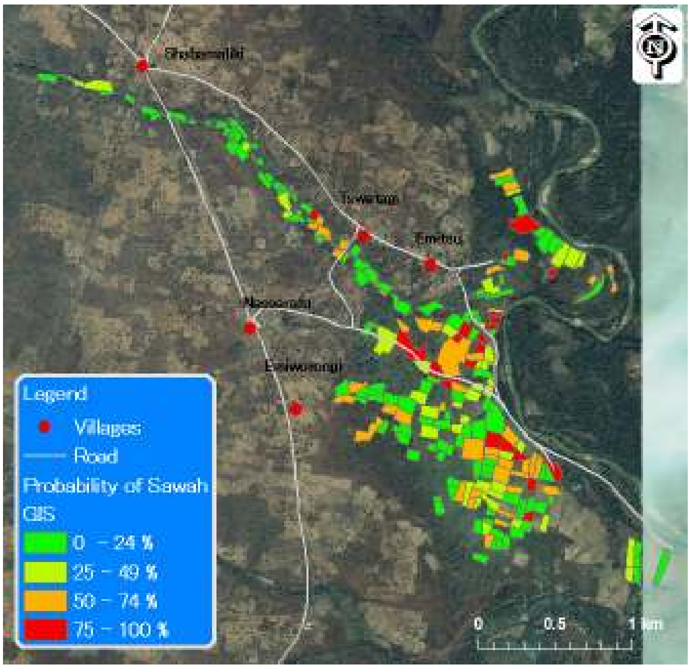


Figure: 4-2: Map of spatial prediction of probability of adopting Sawah, based on parameter estimates of GIS-derived variables

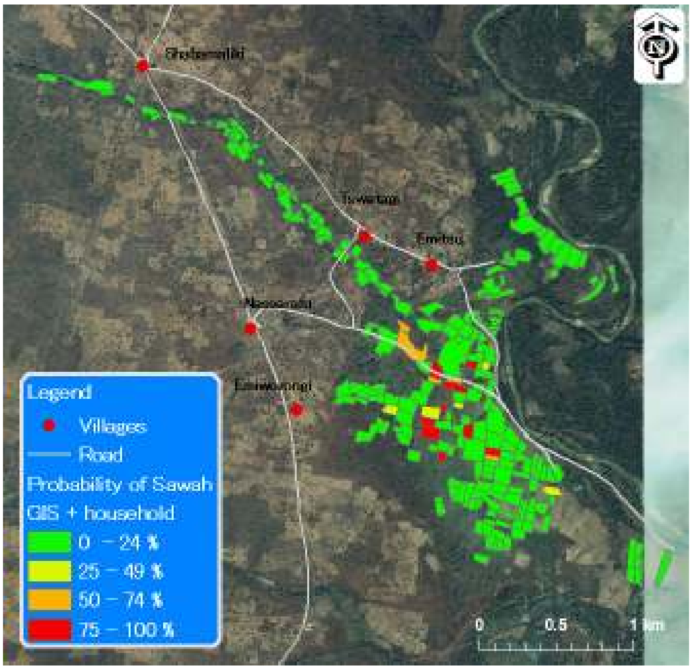


Figure: 4-3: Map of spatial prediction of probability of adopting Sawah, based on parameter estimates of household and GIS-derived variables

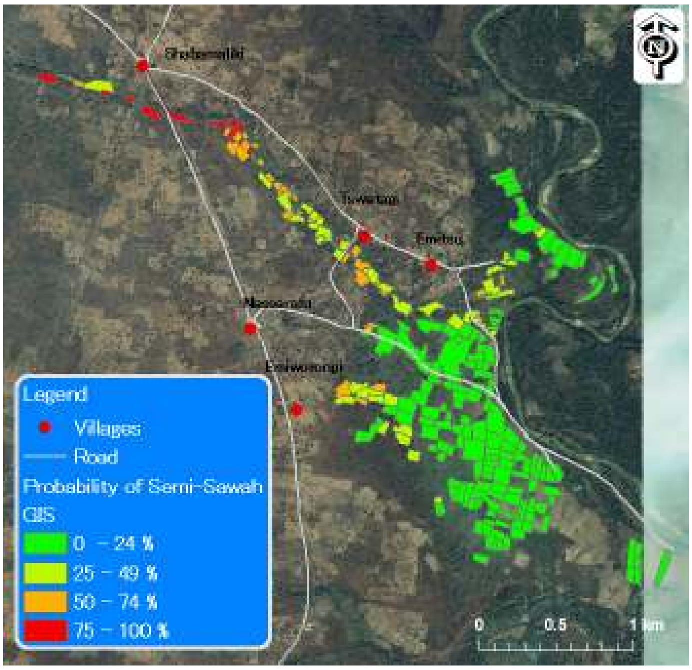


Figure: 4-4: Map of spatial prediction of probability of adopting Semi-Sawah, based on parameter estimates of GIS-derived variables

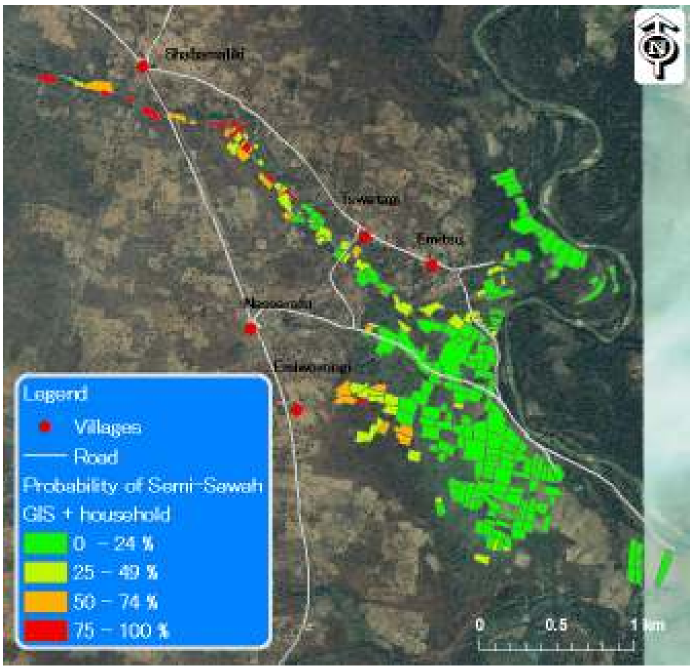


Figure: 4-5: Map of spatial prediction of probability of adopting Semi-Sawah, based on parameter estimates of household and GIS-derived variables

Note: Source of background image is Google Earth

4.2. Probability of Sawah diffusion by farmer's self-efforts

It is proved that Sawah technology has a beneficial effect on yield and income, as noted above; however, the cost of power tiller, not for operating but for purchasing, was not included. Since power tiller was delivered by NGO WIN, Sawah farmers receive the benefit from power tiller by free. Thus, it is uncertain whether Sawah technology will be diffused solely by farmer's independent efforts and taken root in local society in a sustainable way. To clarify this uncertainty, I examined the probability of Sawah diffusion by farmer's self-efforts is examined via simulation. Specifically, I ran the loan simulation is run to test whether rice income increased even if farmers could afford to purchase the cost of power tiller. I assumed that simulation period was 10 years and repayment period was five years.

I selected a village, Emiworongi, as a simulation site. There are two reasons for this selection. First reason is that Emiworongi is most likely to adopt Sawah technology, for it is located only 600 meters away from Nassarafu, a Sawah participate village, and technology is usually diffused through communication (Rogers, 1983). Second reason is that 17 farmers out of 18 already adopted Semi-Sawah, thus, farmers are more likely to adopt Sawah technology if they have a chance. Farmers are divided into two groups by total income according to interview survey: respectively 8 farmers for higher-income group and 9 farmers for lower-income group. Each group is financed 4,000 US dollar which is purchase price of power tiller (Wakatsuki and Masunaga, 2005). According to the farmers that I interviewed, local farmers usually borrow money from relatives or Nigerian Agricultural Co-operative and Rural Development Bank (Agri-bank). But given the facts that most of the relatives have no capacity of 4,000 US dollars and head of Agri-bank told me that the bank can finance only one year, both actors are not likely to be suitable creditors. Two bankers from First Bank and Union Bank in Bida said that they would even finance farmers with respectively 20 percent and 22 percent of interest rate; therefore average rate from two banks is taken as interest rate (i.e. 21 percent). The equal installment repayment method is chosen for repayment method, which makes total purchasing cost 6,134 US dollar.

One of the important assumptions from the above is that power tiller can be operated only in Semi-Sawah plot. The reason is farmers who could not use power tiller cultivated Semi-Sawah instead. Consequently, the probability of converting from Semi-Sawah to Sawah is more likely to be high for Sawah plot in comparison with traditional plot. Income from Semi-Sawah plot will automatically increase to 53 percent, which is an average increase rate according to the result of interview survey. After running the simulation with the period of 10 years, the possibility of Sawah technology diffusing is confirmed by whether the total income of financed group is higher than non-financed group. All conditionality for loan simulation is listed in Table 4-1.

Table 4-1: Conditions of loan simulation

Condition 1	Simulation period is 10 years and natural environment is constant during the period
Condition 2	Dividing farmers into two groups, according to their incomes: 8 farmers for higher-income group and 9 farmers for lower-income group
Condition 3	$4,000 loan by 21% of interest rate which is an average rate of local banks for five years repayment period, which makes $6,134 in total
Condition 4	Employing equal installment repayment method and a self-supporting accounting system
Condition 5	Power tiller works during the period without any trouble
Condition 6	Operating power tiller is confined only to Semi-Sawah plot
Condition 7	According to interview survey, rice income will be improved by 53% automatically by converting from Semi-Sawah to Sawah

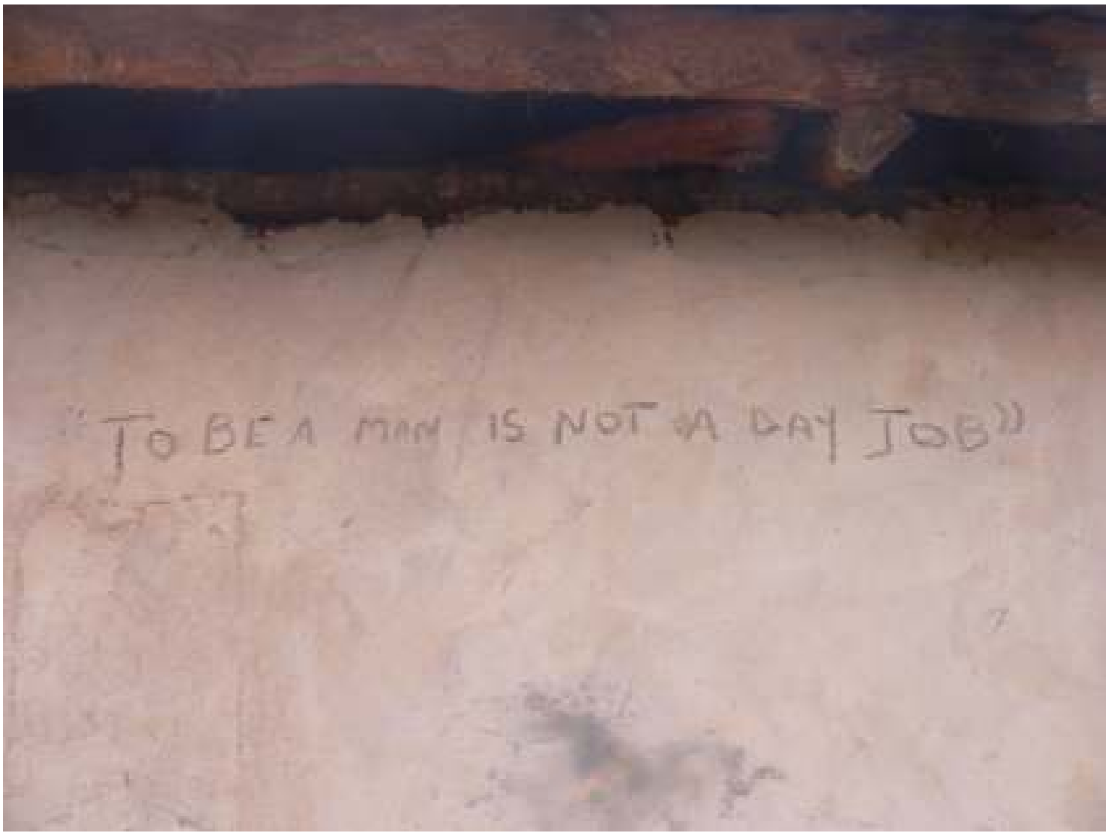
The result of loan simulation is shown in Table 4-2. Column (1) and (2) are non-financed groups and (3) and (4) are financed. In the season of 2008, higher-income and lower-income groups earn respectively 3,588 US dollar and 2,910 US dollar per group. If both groups receive financial assistance by local bank, the amount of rice income would increase to ea. 4,331 US dollar and 3,891 US dollar per group. After five years of repayment period, the result indicates that non-financed groups earn more rice income than financed groups if purchase cost of power tiller is included, which the amounts of differences are respectively 2,422 US dollar for higher-income group and 1,230 US dollar for lower-income group. In the end of the simulation period, however, both groups benefit from loan assistance. For higher-income group, the total amount of rice income increase by 1,289 US dollars as a group; as an individual household it increases by 161 US dollars. A great impact has been seen in lower-income group. Lower-income group earns additional income of 3,676 US dollar as a group and 408 US dollar as an individual household. On these grounds it has come to the conclusion that there is a certain level of possibility of Sawah diffusion by farmer's sole efforts.

Table 4-2: Result of loan simulation

	Higher-income group (1)	Lower-income group (2)	Higher-Income group (3)	Lower-income group (4)
Number of household	8	9	8	9
Loan	No	No	Yes	Yes
Amount of rice income per group without purchase cost in a year*	3,588	2,910	4,331	3,891
Difference between financed and non-financed group*	-743	-981	+743	+981
Amount of rice income per group without purchase cost in 5 years*	17,941	14,549	21,653	19,453
Total amount of rice income per group in 5 years*	17,941	14,549	15,519	13,319
Difference between financed and non-financed group*	+2,422	+1,230	-2,422	-1,230
Total amount of rice income per group in 10 years*	35,883	29,097	37,172	32,773
Difference between financed and non-financed group *	-1,289	-3,676	+1,289	+3,676
Total amount of rice income per household in 10 years*	4,485	3,233	4,647	3,641
Benefit from loan per household *			+161	+408

Note: * indicates unit of US dollar

Chapter 5: Conclusion



Thought is written on the wall, which says "TO BE A MAN IS NOT A DAY JOB"

(Photograph is taken in Shabamaliki, 09/29/2008)

5.1. Main Conclusion

Five important findings through by this study are listed below:

1) Distribution of cropping method around the research area is illustrated by a map. It is impossible to discuss agricultural policy of the area if the map is absent. This kind of micro-level maps of distribution of cropping system may provide valuable information for further development.

2) Increment of economical factors induces adoption of Sawah technology. All working hypotheses which are related to economical factors are supported, i.e. the size of the household, the total paddy areas, religious expenses, and the number of livestock. This result indicates that comparatively rich farmers more likely to adopt Sawah technology.

3) Farmers who cannot adopt Sawah technology copy the essence of Sawah and innovate it to a suitable cropping system which is referred as “Semi-Sawah”. Since farmers innovated Semi-Sawah as easily adoptable technology, most of the factors related to household characteristics are not significant on adopting Semi-Sawah and relatively poor farmers are adopting Semi-Sawah. On the other hand, farmers still continue cultivating the traditional cropping system. This is because farmers make a selective decision on adopting Semi-Sawah by considering the plot conditions. The variables of plot conditions affect significantly on adopting Semi-Sawah and these marginal effects are strong.

4) The benefit of adopting Sawah technology was quantitatively revealed by 2SLS model. With respect to rice yield, Sawah and Semi-Sawah increase 1.1 t ha^{-1} and 0.7 t ha^{-1}, respectively ($p<0.01$). In regard to the rice income, Sawah gain rice income (i.e. 270 US$ ha^{-1}), whereas Semi-Sawah has no significant impact.

5) Many plots have a geographical potential for adopting Sawah technology; however, farmers cannot adopt it in the present conditions. Therefore, I proposed the loan simulation to test whether Sawah technology can be diffused by farmers’ self-efforts in a theoretical sense. After

running the simulation with the period of 10 years, farmers' group earn more income even they afford to purchase the cost of power tiller.

5.2. Further Challenges

The following needs to be considered to elaborate on the analysis of this study:

a) The number of observations for Sawah plot that I have collected is insufficient, i.e. only 29 samples out of 319. This is because many farmers could not use power tiller; so that it is impossible to collect more observations of Sawah plot in the cropping season of 2008. Thus, tracing the transition histories of cropping system to identify the factors of continuance of Sawah cultivation is recommended.

b) Social network should be considered. Because technology is often diffused by communication. Social learning is also an important communicative medium for the diffusion (Conley and Udry, 2005).

c) More diverse spatial information needs to be collected. In this study, the size of the plot, elevation, the distance from the village, and slope rate are used as plot characteristics; however, soil fertility and the distance to irrigation canal, as well as water distribution, are important factors to consider for technology adoption and its impact on yield.

d) Determinant effects strongly on rice income needs to be identified.

e) It is important to consider the goodness of fit of a regression model. Akaike information criterion (AIC) which can measure the goodness of fit should be employed for statistical estimation model.

f) In this study, I only focused on economical benefit. However, considering environmental benefit and cost are also important. Estimating NPV (net present value) would define more detail benefit of Sawah technology.

In addition to the above, the following topics were not included in the scope of this study, but should also be examined for further development.

a) To illustrate land use during dry season is important. This study only focuses on four off-season crops: eggplant, okra, chili pepper, and tomato. Farmers, however, cultivate more diverse off-season crops such as sorghum, maize, sweat potato, and ground nuts. A map of annual cropping system will deepen our understanding on land utilization.

b) Impact of rice milling machine on labor reduction needs to be examined. Traditionally rice milling is a job either of female adults or of children, which gives them substantial burden. Therefore, rice milling machine most likely reduces work after harvesting.

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Appendix A: Pictures of Cropping Method

Figure: Sawah paddy field
(Photograph is taken in Ejiti, 08/01/2008)

Figure: Power tiller
(Photograph is taken in NCRI, 08/05/2008)

Figure: Mound for Semi-Sawah plot
(Photograph is taken in Ejiti, 07/20/2009)

Figure: Land preparation for Semi-Sawah
(Photograph is taken in Ejiti, 08/19/2009)

Figure: Traditional cropping system, Gbaragi
(Photograph is taken in Ejiti, 08/01/2008)

Figure: Land preparation for Gbaragi
(Photograph is taken in Nassarafu, 07/01/2009)

Figure: Traditional cropping system, Baragi
(Photograph is taken in Emitsu, 08/07/2009)

Figure: Land preparation for Baragi
(Photograph is taken in Shabamaliki, 07/18/2009)

Figure: Traditional cropping system, Naafena
(Photograph is taken in Emitsundadan, 08/20/2009)

Figure: Traditionally, farmers plant rice directly
(Photograph is taken in Nassarafu, 07/01/2009)

Figure: Farmers plant about 20-50 seeds in one place
(Photograph is taken in Nassarafu, 07/01/2009)

Figure: Plant spacing in this picture is about 15 cm
(Photograph is taken in Nassarafu, 07/01/2009)

Appendix B: Questionnaire

Module 1 : Characteristics of the Household members	
1	Name of head of household members
2	Age
3	How many wife do you have?
4	How many children do you have?
5	How many people are in your household?
6	How many male whose age 15 - 59 are in your household?
7	How many female whose age 15 - 60 are in your household?
8	What year did you accept Sawah?
Module 2 : Education	
1	What is the highest educational qualification you have acquired?
Module 3 : Rice cultivation	
1	How many Sawah fields do you cultivate? How many traditional paddy field do you cultivate?
2	What are the size of each fields?
3	Are these fields yours or borrowed from someone?
4	What is the source of the water?
5	Did you use WITA4 or traditional seeds?
6	About your Sawah fields, did you complete all activities? 1:Strong Bond 2:Paddling by PT 3:Leveling 4:Line transplanting
7	How many rice sacks were harvested for each plot last year?
Module 4 : Rice Income	
1	How many sacks did you sell in total last year?
2	How many sacks did you sell for the 1st time after harvest?
3	What was the price for 1 sack?
4	How many sacks did you sell for the 2nd time?
5	What was the price for 1 sack?
6	How many sacks did you sell for the 3rd time?
7	What was the price for 1 sack?
8	What was your big item which was bought from rice sell?
Module 5 : Inputs	
1	How many days and people do you hire for leveling?
2	How many days and people do you hire for transplanting?
3	How many days and people do you hire for weeding?
4	How many days and people do you hire for harvesting?
5	How much did you pay for hiring?
6	Did you use power tiller for your plots?
7	How much did you pay for operator?
8	How much did you pay for diesel?
9	How much did you pay for seedling?
10	Did you apply fertilizer?
11	What type of fertilizer did you apply?
12	What was the quantity & the cost of fertilizer?

13	Did you apply herbicides?
14	How much did you buy? (liter)
15	How much did you pay for herbicides?
Module 6 : Off Seasons Crops	
1	Do you make Sweet Pepe, Egplant, Okra, Tomato?
2	How many bags did you sell for each crops?
3	Did you buy seeds?
4	How many people and days did you hire for each crops?
5	How many fertilizer did you apply?
6	How many herbicide did you apply?
7	How many field do you cultivate Sorghum?
8	What is the size for each?
9	Did you buy seeds?
10	How many people and days did you hire for each crops?
11	How many fertilizer did you apply?
12	How many herbicide did you apply?
Module 7 : Livestocks	
1	How many livestocks do you own? Cattle, Sheep, Goats, Chickens, Pigeon, Duck
2	Did you sell your livestock last year?
3	How much did you earn from livestock?
4	What did you buy?
Module 8 : Off Farm Income	
1	Do your household members have off-farm work?
2	What kind of off-farm work do they involve?
3	How many days do your household members work during rainy seasons?
4	How many days do your household members work during dry seasons?
5	Averagely, how much income do you get per day during rainy seasons?
6	Averagely, how much income do you get per day during dry seasons?
Module 9 : Welfare	
1	Did you offer any sacrifice to God during big Sara?
2	What was the cost for sacrifice?
3	How many new clothes did you buy to selebrate Sara?
4	How many adult clothes did you buy to selebrate Sara?
5	What did you eat during big Sara?
6	How much did you spend for food during Sara?
7	Did you buy any big item during big Sara?
8	What was the cost for item?
Module 10 : Communication	
1	When you have a problem in farming, which house do you go to ask for help?
2	Do you know Sawah leader's sell-phone number?
3	Have you ever ask help or advice to Sawah leader about Sawah?
4	Have you ever ask help or advice to Sawah leader about other than Sawah?
5	Do you know NGO-stuffs' sell-phone number?
6	Do you know where he lives?

Appendix C: Abstract of presentation at Japan Association for African Studies

西アフリカにおける小型耕耘機を利用した小規模灌漑水田開発の経済的および社会的影響評価 —ナイジェリア国ビダ市近郊の内陸小低地を事例にして—

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Socioeconomic Impact Assessment of Development of Wet Rice Fields with Small-Scale Irrigation Scheme Using a Power Tiller in West Africa—A Case Study of Inland Valleys in Bida, Nigeria

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【背景と目的】多くの西アフリカ諸国においてコメは主食の一つである。しかしながら，人口増加と主に都市部での需要の高まりから消費量に生産量が追い付いていかず，コメの増産は緊要の課題となっている。一方，西アフリカには主要稲作生態系である陸稲栽培に比べて高い生産性の見込める集約的水稲栽培に適した内陸小低地が多数存在している。したがって，水田開発ポテンシャルは比較的高いと考えられているが，多くの場合は未開発のまま取り残されているか，あるいは，伝統的な粗放栽培が優先している[3]。本研究は，ナイジェリア国およびガーナ国で顕著な成果を上げている農民の自助努力による小型耕耘機を利用した小規模灌漑水田開発事業[4]を研究対象とし，ナイジェリア国ナイジャー州ビダ市近郊の農村を事例として農民への経済的・社会的影響評価を実施した。なお，ビダ市近郊に居住するヌペ族は伝統的に内陸小低地における水稲栽培に従事しているが，概してその生産性は低い[5]。

【調査方法】現地調査は 2008 年 8〜10 月にビダ市近郊の農村 5 ヵ村（基本サンプル数 96）で実施した。農民へのインタビュー調査を主体とし，補助的にフィールドでの農地面積・収量を測定した。集落 5 カ村のうち 4 カ村では水田開発事業が実施されている。また，残り 1 カ村は対照区として伝統農法を継続している集落を選出した。

【結果と考察】2007 年シーズンの平均収量は伝統的準水田で 1.4±0.8 t ha^{-1} であるのに対し，開発水田では 2.8±1.1 t ha^{-1} と有意（$P < 0.05$）に高かった。一方，水田を導入することで労働力（伝統稲作 242±173. US\$ ha^{-1} vs. 水田稲作 264±706 US\$ ha^{-1}[6]）および肥料の投入量（伝統稲作 76±51 US\$ ha^{-1} vs. 水田稲作 105±102　US\$ ha^{-1}）の増加が認められたが、それらを差し引いた自家労賃を含む純利益は水田稲作農家（397±411 US\$ ha^{-1}）と伝統稲作農家（157±330 US\$ ha^{-1}）よりも有意（$P < 0.05$）に高く，水田の開発により農家の稲作収益が増加していることが示唆された。また，農家の資産の一つとして家畜（牛、ヤギ、羊、鶏、鳩、アヒル）を調査したところ，水田稲作農家の家畜保有数（22±21 heads $household^{-1}$）は伝統稲作農家（15±13 heads $household^{-1}$）よりも大きくなる傾向が見られた。この傾向は家畜販売額にも反映され，水田稲作農家（257±422 US\$ $household^{-1}$）が伝統稲作農家（152±184 US\$ $household^{-1}$）よりも大きい収入を得ていた。また，伝統稲作農家の 54%が日々の食料の購入のために家畜を売却していたのに対し、水田稲作農家は、その 40%が宗教的式典に、30%を家やバイクなど他の資産の購入に当てていた（食料購入は 15%）。以上の結果より、小型耕耘機を用いた小規模灌漑水田の導入により低地における稲作の収量お呼び収益が改善されることで，農民はより多様な資産を保有し，より豊かな社会生活を営んでいることが示唆された。

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