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Farming Strategy of African Smallholder Farmers in Transition from Traditional to Alternative Agriculture: The Case of the Nupe in Central Nigeria

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Abstract

It is worthwhile to understand farming strategies of smallholder farmers in sub-Saharan Africa, especially those of farmers who are in transition from traditional to alternative agriculture in terms of adoption of innovative technologies. In a case study of inland valleys in central Nigeria, we investigated the farming strategy of Nupe farmers who have a long-term tradition of wet rice cultivation and indigenous methods of land preparation for soil, water and weed management. In this region, a new method of land preparation has recently been introduced along with a recommendation to use improved seeds and chemical fertilizers. Our findings reveal that Nupe farmers directly sow traditional seeds and apply a marginal amount of fertilizer to paddy plots prepared by labor-saving methods on drought-prone hydromorphic valley fringes and flood-susceptible valley bottoms, whereas they preferentially transplanted improved seedlings and applied a relatively large quantity of fertilizer to paddy fields prepared by a labor-intensive and mechanized method on a valley position where they can access to optimum water condition (less risky against the drought and flood).

Keywords: Indigenous knowledge, Land preparation method, Rice cultivation, Risk management, Technology adoption

JEL classification: N57, O33, Q16

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methods on drought-prone hydromorphic valley fringes and flood-susceptible valley bottoms, whereas they preferentially transplant improved seedlings and apply a relatively large quantity of fertilizer to paddy fields prepared in a labor-intensive manner or mechanized mode in a valley position where they can access optimum water conditions for rice growth. Although Nupe farmers have to compromise with a low rice yield and marginal economic return, they can minimize the risk attached to the labor and resource investment in fields that are environmentally unfavorable for rice cultivation. In contrast, Nupe farmers enjoy a higher rice yield and economic return due to preferential application of the new technologies with higher investment in the field under favorable conditions. This strategy of rice farming represents farmers' efforts to increase return on investment while reducing environmental risk by employing selective application of new agricultural technologies and labor input according to local environmental settings.

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ABSTRACT

It is worthwhile to understand farming strategies of smallholder farmers in sub-Saharan Africa, especially those of farmers who are in transition from traditional to alternative agriculture in terms of adoption of innovative technologies. In a case study of inland valleys in central Nigeria, we investigated the farming strategy of Nupe farmers who have a long-term tradition of wet rice cultivation and indigenous methods of land preparation for soil, water and weed management. In this region, a new method of land preparation has recently been introduced along with a recommendation to use improved seeds and chemical fertilizers. Our findings reveal that Nupe farmers directly sow traditional seeds and apply only a marginal amount of fertilizer to paddy plots prepared by labor-saving methods on drought-prone hydromorphic valley fringes and flood-susceptible valley bottoms, whereas they preferentially transplant improved seedlings and apply a relatively large quantity of fertilizer to paddy fields prepared in a labor-intensive manner or mechanized mode in a valley position where they can access optimum water conditions for rice growth. Although Nupe farmers have

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to compromise with a low rice yield and marginal economic return, they can minimize the risk attached to the labor and resource investment in fields that are environmentally unfavorable. In contrast, Nupe farmers enjoy a higher yield and economic return due to preferential application of the new technologies with higher investment in the field under favorable planting conditions. This strategy of rice farming represents farmers' efforts to increase returns on investment while reducing environmental risk by employing selective application of the new technologies and labor input according to local environmental settings.

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1. Introduction

Traditional farming systems of smallholder farmers in sub-Saharan Africa are often characterized by a pattern of 'low-input, low-output' and 'small-scale, multi-crop' production, which ensures the minimization of risks while maintaining basic subsistence but perpetuates low productivity and marginal economic benefit (JICA/AGRA, 2008). These traditional systems, however, have a limited capacity to feed human communities and have been unable to meet the growing human needs in recent decades (Brady, 1996; Sanchez et al., 2005). Low productivity in traditional farming systems is the fundamental root of hunger and malnutrition which is prevalent across sub-Saharan Africa (Sanchez, 2002; Sasson, 2012), and traditional farming is sometimes blamed for soil degradation, deforestation, ecosystem disruption and biodiversity loss (Hirose and Wakatsuki, 2002; Lamb et al., 2005). Alternative agricultural systems are in great demand accordingly (Brady, 1996; Sanchez et al., 2005).

The alternative systems primarily target crop productivity enhancement and may include appropriate use of the Green Revolution technologies, e.g., improved seeds, chemical fertilizers, irrigation facilities and mechanization (Otsuka, 2006; Otsuka and Kalirajan, 2006; Sanchez et al., 2009; Sasson, 2012). However, the introduction of the Green Revolution technologies has met with only partial success, and their immediate and uniform adoption has been quite rare (Feder et al., 1995). For instance, in sub-Saharan Africa, the rate of adoption of improved seeds is still low (Evenson and Gollin, 2003) and fertilizer use remains at a marginal level in major areas of the region (Otsuka, 2006). Still, successful stories of technology adoption and resultant production boosts in agriculture have been increasingly reported in some parts of the region (Sanchez et al., 2009; Sanchez, 2010). We therefore believe that African farming systems are now positioned widely in transition from traditional to alternative systems.

On the other hand, indigenous farmers have acquired knowledge from generations of experience and experimentation, as they have had to adapt their agricultural systems to harsh and insecure environmental conditions using locally available natural resources (Ishida et al., 1998). It has become increasingly recognized that understanding of traditional agricultural systems and indigenous farming strategies sheds light on new insights and innovative ideas when transferring new technology to the farmers in rural development projects as the agricultural ethics of any ethnic group may originate from indigenous knowledge. Adoption of new technologies may exert influence on the indigenous system and strategy. It is, therefore, worth investigating changes in the farming strategy of smallholder farmers after transferring the technologies to local communities.

In the present study, we examine the farming strategy of Nupe farmers in inland valleys[1)] of central Nigeria. The Nupe have a long-standing tradition of wet rice cultivation (Nadel, 1942; Yahaya, 2003) and have developed distinctive methods of land preparation which have advantages in weed suppression, soil fertility management and water control (Ishida et al., 1998, 2001). In this area, a new land preparation method of Asian origin, called *Sawah*, was introduced in the early 1990s by a Japanese-funded action research project (Hirose and Wakatsuki, 2002), but real effort for the dissemination of *Sawah* was begun in 2003 by a local NGO (Fu et al., 2009). These efforts were made in tandem with a recommendation to use an improved rice variety and chemical fertilizer (Hirose and Wakatsuki, 2002; Fu et al., 2009). Nupe farmers increasingly employ the improved seeds and fertilizers as well as *Sawah* so as to improve rice yield and gain the economic benefit. This situation can be regarded as a transitional stage from traditional to alternative farming systems. Although the general characteristics of the traditional farming system and indigenous ways of land preparation in the Nupe's rice-based farming system have been reported elsewhere (Hirose and Watatsuki, 2002; Ishida et al., 1998, 2001), the detailed agronomic practices, productivity and economic characteristics of this traditional system still remain largely unknown, and more importantly, the influence of the adoption of the given new technologies on the traditional farming system has not been documented.

The aim of the present study is to explore the farming strategy of Nupe rice farmers in relation to technology adoption, resource application and labor investment as a case study of the farming strategy of African smallholder farmers in transition from traditional to alternative agriculture.

2. Study Area

The study area is located in the suburb of Bida, Niger State, in central Nigeria (Fig. 1) where the Nupe are the dominant ethnic group. The Niger State is a major granary of rice and has the largest rice cultivation area in Nigeria (National Food Reserve Agency, 2007). This area is situated in the southern Guinea savanna agro-ecological zone, which has a mean annual precipitation of about 1,100 mm and a mean annual daily temperature of approximately 23°C. The rainy season normally lasts for six to seven months (April/May–October/November) followed by five to six months of the dry season. The inland valley is the predominant topographic feature of the study area, which is the seasonal headwater swamp of the river system and occurs between the ridges of the gently undulating peneplain. Some inland valleys have a natural spring or seepage water, some of which is still available during the dry season. The location and availability of such water sources seem to be dependent on topography and underground geology. Soil characteristics in the Bida area are characterized by sandy texture and siliceous or kaolinitic mineralogy representing very poor soil fertility status at an advanced weathering stage (Ishida et al., 1998; Abe et al., 2006, 2007a, 2009b), which have been developed on Mesozoic (Cretaceous) sedimentary rock known as Nupe Sandstone (Esu, 1986).

The ancient Nupe occupied the floodplains in the valley of the River Niger and the River Kaduna at least by the fourteenth century, and their economic basis seems to have been the cultivation of African rice (*Oryza glaberrima* Seud.), fishing and river trading (Blench, 1989). Bida has been the capital town of the old Nupe Kingdom since Fulani nomads conquered Nupe peasants in the early 19th century (Nadel, 1942). Bida is the second largest city in the Niger State and is widely known as the political and cultural center of Nupeland where the emir, who is called the *Etsu Nupe*, resides. There are probably over a million Nupe in Bida; they are predominantly Muslims (Yahaya, 2003). Most of the population consists of smallholder farmers living on a subsistence level and conducting wetland rice farming, rainfed dryland crop cultivation, animal husbandry and some fishing from the rivers (Hirose and Ishida, 2002). The Nupe have a long-established tradition in lowland rice farming and eat rice more than any other ethnic group in Nigeria. An indigenous rice-based farming system in the inland valleys and river floodplains has been developed by the Nupe (Wakatsuki, 1990; Hirose and Ishida, 2002; Ishida et al., 1998, 2001), with partial development of a traditional irrigation scheme (Fu et al., 2010). The majority of the farmers who can access the inland valleys or floodplains, therefore, enjoy rice production as a major and profitable venture. It is said that, in the Nupe culture, anyone who does not plant rice will not be regarded as a real farmer. Local farmers usually sell more than 50% of their harvested paddy rice and keep the rest for self-consumption and seed planting for the next season (Fu et al., 2010). There are locally important markets in Bida and another nearby town called Doko.

3. Farming Systems

3.1. General description

Nupe farmers widely cultivate rice (*Oryza sativa* L.) in inland valleys during the rainy season, while they grow dryland crops in the upland. Some farmers who can access irrigation water or lands where residual moisture is available also cultivate some dryland crops and/or vegetables in the valley bottoms during the dry season. Major dryland crops grown during the rainy season are guinea corn (*Sorghum viscor* L.), pearl millet (*Pennisetum glaucum* (L.) R. Br.), white yam (*Diascorea notundata* L.), cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* L.), groundnuts (*Arachis hypogaea* L.), cowpea [*Vigna unguiculata* (L.) Walp.], cocoyam (*Colocasia esculenta* L.) and egusi melon (*Colocynthis citrullus* L.) (Hirose and Ishida, 2002). Major vegetables planted for dry season farming were sweet pepper (*Capsicum annuum* L.), garden egg (*Solanum aethiopicum* L.), okra (*Abelmoschus esculentus* (L.) Moench) and tomato (*Solanum lycopersicum* L.) in addition to some dryland crops such as cassava, sweet potato and cowpea (Fu et al., 2010).

Nupe farmers usually start with dryland farming on an upland plateau when rainfall begins in May (in normal years). The Nupe's dryland farming system is based on a typical slash-and-burn method which can be observed widely in other areas in Nigeria (Hirose and Ishida, 2002). It usually requires two to three months after rainfall begins for valley bottoms to receive sufficient water to support rice cultivation. Land clearing (weeding) is the first operation for rice cultivation; the majority of farmers in the study area use commercial herbicides for this purpose. Popular herbicides include paraquat and glyphosate. Following the land clearing with the herbicides, they begin land preparation using a traditional hoe (*zukun*); they start by breaking down the mounds (*Ewakogi*) (if any) which they made for the off-season crops in the previous dry season and then prepare small- to medium-sized flat basins by maintaining/rehabilitating the bands. At the same time, farmers prepare a nursery or directly sow the seeds inside the basin. Rice farmers use traditional rice cultivars[2)] which require 150 days or more to mature as well as improved varieties with a shorter growth period. Weeding may be done three or four times during rice growth; the first and second weedings are often conducted one and two months after seeding, respectively. Fertilizer, if available, may be applied just after the second weeding. After reaping the rice in December or January, Nupe farmers prepare the land again for the off-season crop cultivation.

3.2. Land preparation methods

Nupe farmers in the Bida region utilize distinctive methods of land preparation for their rice-based farming system. Ishida et al. (1998, 2001) classified the Nupe's traditional land preparation methods into seven categories: (1) *Gbaragi*, (2) *Baragi*, (3) *Togogi kuru*, (4) *Togoko kuru*, (5) *Togogi naafena*, (6) *Togoko naafena* and (7) *Ewokogi*. Our survey confirmed that Nupe farmers are still using these land preparation methods in the region. In general, *Togogi* refers to land preparation for a small plot, whereas *Togoko* denotes a larger plot. *Kuru* indicates a basin closed by bund construction, which is used in certain convex positions where the field requires an enclosure to retain water; in contrast, *Naafena* indicates an unclosed basin with hook-shaped ridges in a lower position, and it may bear some resemblance to a dale that allows water to flow down to the fields located in lower regions (Ishida, 1998). However, as the difference between *Togogi kuru* and *Togoko kuru* and between *Togogi naafena* and *Togoko naafena* lies in the basin size only, their definitions are not so clear and differ among the farmers. Hence, the pairs *Togogi kuru*/*Togoko kuru* and *Togogi naafena*/*Togoko naafena* were categorized together and hereafter are referred to as *Togogi/Togoko kuru* and *Togogi/Togoko naafena*, respectively. *Ewakogi* involves mounds which are about 0.4 to 0.6 meters in height and 0.5 to 1.0 meters in diameter, whereas *Togogi/Togoko naafena* involves hook-shaped ridges within a banded basin. In these land preparation systems, Nupe farmers often cultivate cassava, sweet potato, yam, cocoyam and vegetables on the mounds and ridges. In the following sections, *Ewakogi* and *Togogi/Togoko naafena* will not be discussed because *Togogi/Togoko naafena* was hardly observed in the study region and *Ewakogi* was mostly used for dryland crop cultivation.[3)] The Nupe's method of land preparation in wetlands is often sequential through a year. Each method is seasonally modified, such as by displacing the soil of ridges and mounds or collecting surface soil to form ridges and mounds, with each sequence of the pattern depending on the conditions, such as rice and weed growth, water availability and crop varieties (Ishida et al., 1998, 2001). One land preparation method for rice farming in the rainy season may be associated with another land preparation method used for off-season crop cultivation in the dry period (Ishida et al., 1998). After the rice harvest, banks and ridges are firstly broken, except for the main bands.

3.2.1. Gbaragi

Gbaragi involves many linear or winding parallel ridges (about 0.2 to 0.4 meters in height, 0.3 to 0.4 meters in width with 0.2 to 0.4 meters spacing in a row) in a basin surrounded by bunds (0.3 to 0.5 meters in width, 0.3 to 0.5 meters in height). The banks are normally bigger and stronger than ridges inside the basin (Fig. 2). Rice (10 to 30 seeds per fill) is directly sown on ridges at a 0.2 to 0.3 meter interval. The first weeding may be done 1 to 1.5 months after seed sowing using a *zukun*, a smaller hand hoe (*degba*) or machete (*gada*). The farmers incorporate weeds into the soil by tuning the surface soil inside out and place that soil in the space between the ridges The bunds and ledges become smaller than those at the time of land preparation and the basins look relatively flat after the first weeding. The second weeding may be done by hand 2.5 to 3.5 months after seed sowing. These cultivation characteristics exhibit many similarities to those for sorghum, millet and beans in the dryland, except for bund construction.

3.2.2. Togogi/Togoko kuru

Togogi kuru and *Togoko kuru* both refer to a random square-shaped basin system having divided closed square blocks so that farmers can collect and retain water within the basin (Fig. 3). This is the main difference from *Togogi/Togoko naafena*, which has opened hooks and always allows water to flow down to lower fields. The height of the ridges is about 0.40 to 0.6 meters. Only the size of each block determines the difference between *Togogi kuru* and *Togoko kuru*; the length of a side in *Togogi kuru* is about 2 to 3 meters, while that in *Togoko kuru* is 5 to 15 meters. The plot size in *Togogi/Togoko kuru* may be determined by microtopography. Ishida et al. (1998) reported that *Togogi kuru* tends to be distributed on sloping areas as many small ridges were required for water control, but *Togoko kuru* appears on flat surface areas where not so many ridges are needed for water control.

3.2.3. Baragi

Baragi has neither mounds nor ridges inside the basin surrounded by banks (Fig. 4). The basin floor is manually tilled by turning the topsoil (up to 5–15 cm in depth) upside down so that weeds are incorporated into the soil. The land surface looks rugged just after the land preparation, but it becomes relatively smooth and flat following some rainfall that collapses the soil clods. The size of the bank is often smaller than that of *Togogi/Togoko kuru* and *Gbaragi*.

3.2.4. Sawah

Sawah is a new and exogenous land preparation method which was recently introduced to the Bida region by a Japan-funded project. *Sawah* is a term of Malayo-Indonesian origin which indicates an Asian-type paddy field having a submerged flat basin surrounded by bunds, and it may be connected to irrigation and drainage canals for water control (Abe and Wakatsuki, 2011; see Fig. 5). The soil within the basin is usually subject to wet tillage (puddling) prior to the transplanting of rice seedlings. In the study area, the puddling operation was mostly done by small machinery (Hirose and Wakatsuki, 2002). Two-wheel walking tractors, so-called power tillers made by Kubota (Japan) or Shakti (India) (Wakatsuki et al., 2010), were provided by the Japan-funded action research project. These tractors are maintained and handled by the villages. A farmer who wants to use a power tiller in his fields summons a power tiller operator and pays for the fuel and the operator’s allowance.

4. Field Survey and Methodology

4.1. Household interviews

A household survey was conducted in the suburb of Bida during June to August 2009. We interviewed 132 household heads in total who were selected at random from eight villages where farmers have access to the rice fields in inland valleys: Ejeti, Emitsun dadan, Nassarafu, Shabamaliki, Amgbasa, Emitsu, Emiworongi and Tsuwatagi (Fig. 1). The first four villages have been enjoying a local extension service on *Sawah* development, while the latter four have not (Takahashi et al., 2012). The coverage of household heads interviewed was 82% of the total number (n = 161) of the household heads in the surveyed villages. The general characteristics of the household heads in the surveyed villages are shown in Table 1. The interviewed household heads cultivated 313 paddy fields in total, and information was collected for each paddy field. The land preparation method applied to the rice fields was assessed in farmers' interviews and was subsequently confirmed by the field inspection. Rice production gain was calculated by multiplying the amount of rice sold by the unit price at the time the rice was sold by the farmers. The labor hired for each type of work was estimated by dividing the hired labor cost by the mean standard wage for labor in the study region.

4.2. GPS survey

We created a geo-referenced map using the global positioning system (GPS). The GPS information was collected using a hand receiver (GPSMAP60CSx, Garmin Ltd., Kansas, USA) with an accuracy of three to five meters. The locations and square areas of the fields were recorded by the GPS receiver along with the land preparation method.

4.3. Rice yield measurement

The rice yield of each paddy plot was computed by dividing the rice production obtained from the plot by the measured plot area. Rice production was estimated by multiplying the number of rice (paddy) bags obtained from the plot as stated in the farmers' interviews multiplied by 75 kg, which is the approximate weight of a 100-kg sack filled by rice (paddy) grains in the study area.

4.4. Farmers' trial land preparation

To analyze the labor requirement and the detailed agronomic practices in traditional methods of land preparation, a field trial was conducted with farmers' participation. We invited 15 rice farmers from three villages, i.e., Ejeti, Nassarafu and Ekpagi (a village near Ejeti), for a time trial of land preparation. Each farmer tried *Gbaragi*, *Baragi* and *Togogi/Togoko kuru* in a 5-meter by 5-meter plot[4)], respectively. The trial was done in duplicate for each land preparation method by each participating farmer, and the means of each of the two trials were recorded for analysis.

4.5. Supplemental interview survey

A hundred household heads were randomly selected from the same villages investigated in the main survey and were invited to a supplemental interview during September through October 2010. The household heads were asked to state their reasons for selection of the land preparation methods for 204 paddy plots.

4.6. Data processing and analysis

Statistical analysis was performed by SPSS 15.0 (SPSS Inc., Chicago, USA). All plot data were considered to be independent and random, even though some of them originated from the same household heads. The land preparation method was considered to be a fixed effect, and a multiple comparison was made by the Scheffe test to detect a statistically significant difference ($P < 0.05$) among the means. GPS information was normalized and incorporated into a Google Map using ArcGIS 9.3

(Esri, California, USA).

5. Results

5.1. Land preparation and agronomic practices

Gbaragi was the most frequently used method for rice cultivation by the Nupe farmers in the study area, among all the land preparation methods (Table 2). *Togogi/Togoko kuru* followed *Gbaragi* by a narrow margin. *Baragi* and *Sawah* were much less frequently used compared with *Gbaragi* and *Togogi/Togoko kuru*. The mean distance from the residents' village to the paddy plot was found to be significantly larger for *Gbaragi* than for *Togogi/Togoko kuru*, *Baragi* and *Sawah*, but no significant difference was found among the latter three land use systems. Average ground area per paddy plot was significantly smaller for *Togogi/Togoko kuru* than for *Gbaragi* and *Sawah* An improved cultivar (WITA4) was transplanted mostly in *Togogi/Togoko kuru* and *Sawah*, while traditional cultivars were predominantly sown directly in *Gbaragi* and *Baragi*. Nupe farmers usually prepare a nursery in part of their paddy fields and transplant 2 to 5 seedlings at 3 to 5 weeks of age to *Togogi/Togoko kuru* and *Sawah* at a plant population of 7 to 12 hill m^{-2}, whereas they dibble, place 10 to 30 seeds and cover them with soil in *Gbaragi* and *Baragi* resulting in a plant density of 3 to 6 hill m^{-2}.

The farmer trial revealed that plant population per hill after seedling establishment was approximately five times higher in *Gbaragi* and *Baragi* than in *Togogi/Togoko kuru* and *Sawah* (Table 3). In contrast, the number of rice hills per unit of ground area was two to three times lower in *Gbaragi* and *Baragi* than in *Togoko kuru* and *Sawah*. There was no significant difference in number of the seeds sown per hill in *Gbaragi* and *Baragi* or in the number of seedlings transplanted per hill in *Togoko kuru* and *Sawah*. Moreover, regarding the land preparation, the participating farmers spent almost twice as much time doing that for *Togoko kuru* as for *Gbaragi* and *Baragi*. Also, the transplanting work in *Togoko kuru* and *Sawah* demanded more than twice as much time as the seeding operation in *Gbaragi* and *Baragi*. In addition, nursery preparation and seedling uploading required almost the same time as spent for the seeding operation. As a result, to start up rice cultivation, *Togogi/Togoko kuru* called for more than two to three times as much time in total than did *Gbaragi* and *Baragi*. Although thanks to the help of the power tiller, much less labor was required for the preparation of *Sawah* than for *Togogi/Togoko kuru*, *Sawah* demanded a significantly larger amount of labor, especially for transplanting work, than *Gbaragi* and *Baragi*.

Nupe farmers selected a specific land preparation method mainly due to water control (47%), ease of work (29%) and better harvest (13%) (Fig. 3). In particular, water control was preferentially mentioned by the farmers as reasons for selecting *Gbaragi* and *Baragi*. In addition, a few farmers also listed other reasons such as soil properties, effect of custom and weed control.

5.2. Hired labor requirement and resource input

Togogi/Togoko kuru demanded significantly more hired labor for the land preparation than did *Gbaragi*, *Baragi* and *Sawah* (Table 4). Moreover, *Togogi/Togoko kuru* and *Sawah* called for additional hired labor for transplanting which was almost same as that required for land preparation in *Togogi/Togoko kuru*. It was also confirmed during the interview with the farmers that the Nupe farmers hardly hire the labor for the seed sowing in *Gbaragi* and *Baragi* and that their wives and children help with this work instead (Sakyu, personal communication). *Togogi/Togoko kuru* had the largest demand for hired labor, for the weeding, which was significantly larger than that in *Baragi* and *Sawah*. *Gbaragi* demanded an intermediate amount of hired labor without any significant difference from the other types of paddy plots. The hired labor for harvesting produced the largest average value in *Togogi/Togoko kuru* which showed a significantly higher mean value than the other land preparation methods. As a result, *Togogi/Togoko kuru* produced the highest value for total labor hired for rice production, and the figure was significantly higher than that for the other land preparation methods.

The interview survey with the farmers found that the amount of NPK compound fertilizer applied to the paddy plots was the highest in *Togogi/Togoko kuru* (Table 5). Less than half the amount of NPK fertilizer was applied to *Gbaragi* and *Baragi* as compared with *Togogi/Togoko kuru*, with a significant difference between the former and the latter. *Sawah* received an intermediate amount of NPK fertilizer without any significant difference from the other land preparation methods. The largest amount of urea was applied to *Togogi/Togoko kuru* among the land preparation methods; the other land preparation methods used less than half of the urea amount applied to *Togogi/Togoko kuru*, and no significant difference was seen among them. As a consequence, total nitrogen (N) applied to the paddy plot was highest in *Togogi/Togoko kuru*, at more than double the amount in *Gbaragi* and *Baragi*. *Sawah* showed an intermediate nitrogen application rate without any significant difference from the other land preparation methods. The largest amount of herbicide was applied to *Togogi/Togoko kuru*, but a significant difference was only found between *Togogi/Togoko kuru* and *Baragi*.

5.3. Rice productivity and income generation

Rice (paddy) yield was as follows, from highest to lowest: *Sawah* > *Togogi/Togoko kuru* > *Gbaragi* > *Baragi* (Fig. 4). There was a significant difference in rice yield between *Sawah* and *Togogi/Togoko kuru* and between *Togogi/Togoko kuru* and *Gbaragi* but not between *Gbaragi* and *Baragi*. The grain yield in *Gbaragi* and *Baragi* was very low. *Sawah* produced rice grains at least twice as large as those in *Gbaragi* and *Baragi* and also had the advantage in rice production over *Togogi/Togoko kuru*.

In addition, only *Sawah* required an operation cost of about US$20 per hectare for the power tiller for soil puddling during land preparation. There was no significant difference in total production cost between *Sawah* and *Togogi/Togoko kuru*, but it was significantly higher in *Gbaragi* and *Baragi*. The production cost for *Gbaragi* and *Baragi* was almost twice as high as that for *Sawah* and *Togogi/Togoko kuru*.

The high rice yield in *Sawah* resulted in the highest economic gain from rice production per unit of ground area (Table 5). *Togogi/Togoko kuru* realized a significantly smaller rice production gain than *Sawah* but realized a larger rice production gain than *Gbaragi* and *Baragi*. The average income obtained from *Sawah* was nearly US$1000 per ha, which was about 1.5 times higher than that from *Togogi/Togoko kuru* and more than twice as high as that from *Gbaragi* and *Baragi*.

5.4. Paddy plot distribution over the landscape

Figure 5 shows an inland valley system that includes paddy plots tenanted by five surveyed villages: Nassarafu, Shabamaliki, Emitsu, Emiworongi and Tsuwatagi. Most farmers rented paddy plots close to their resident villages. However, some farmers, especially ones from Shabamaliki, rented paddy plots relatively far from the villages. Geographical distribution of the paddy plots prepared by different land preparation methods indicates that *Togogi/Togoko kuru* was spread across the middle to the upper slope of the inland valley system (Fig. 6). *Gbaragi* and *Baragi* were located predominantly on the upper and lower slope of the valley system, respectively. *Sawah* was found mostly on the middle slope of the valley system. These trends of distribution of paddy plots are endorsed by Fig. 7, which illustrates the rice yield in paddy plots over relative elevations[5)].

6. Discussion

Our findings reveal that the Nupe farmers cultivated rice in *Togogi/Togoko kuru* and *Sawah* mostly by transplanting the improved cultivars, but in *Gbaragi* and *Baragi* did so predominantly by sowing the traditional seeds directly in the plot (Table 2). The Nupe farmers widely believe that the improved cultivars, i.e., high-yielding varieties in this case, can deliver a higher yield than the traditional cultivars only when the improved cultivars grow up in favorable conditions with application of fertilizers, whereas the traditional cultivars are hardy enough to withstand unfavorable conditions, sometimes resulting in better yield and economic returns than the improved cultivars. In fact, *Grabagi* and *Baragi* planted with the traditional cultivars were found to have mostly unfavorable conditions. *Gbaragi* was predominantly found at the bottoms of the inland valleys where a substantial risk of occasional flood exists, and *Baragi* was preferentially prepared at the hydromorphic valley fringe at a higher slope position where rice is often exposed to water shortage and drought (Figs. 6 and 7). Accordingly, the Nupe farmers preferentially used the traditional seeds in *Baragi* and *Gbaragi* even though they still possessed a stock of improved seeds.

Gbaragi can protect rice from occasional floods, especially at an early vegetative stage of rice growth as rice grows on the ridges (about 0.2–0.4 m in height) (see Fig. 2). *Baragi* has a closed flat basin surrounded by banks so that it can collect and retain water within the basin. The ridge culture in *Gbaragi* would also be beneficial to prevent an iron toxicity problem in rice (Winslow et al., 1989; Ishida et al., 1998) which is one of major constraints in wetland soils in West Africa (WARDA, 2002). On the other hand, *Togogi/Togoko kuru* and *Sawah* were distributed on the middle slope between the valley bottom and fringe (Figs. 6 and 7). Hydrological conditions in this location are favorable for rice cultivation by Nupe farmers as the deep food rarely reaches this location but richer water is available for rice cultivation than on the upper slope. It is also relatively easy for the farmers to control water through their own efforts in this slope position. Hence, Nupe farmers use improved cultivars preferentially in this environment. This is consistent with the result of our interview survey since Nupe farmers stated water control as the most important reason for their selection of the land preparation method (Fig. 3). Similar results have been delivered in other studies, as follow. Fu et al. (2009) reported that Nupe farmers who had experience with *Sawah* mentioned the better yield and water control most frequently about the advantages of *Sawah*. Also, water regime was presented as one of the three factors by Ishida et al. (1998, 2001) that determines the Nupe's land preparation method. However, the other two factors, i.e., microtopography and soil fertility, were noted by many fewer farmers than by those who mentioned water control and yield in our study. The hydrological gradient is a major cause of toposequential variation in rice productivity and soil fertility in the inland valleys of West Africa (e.g., Smaling et al., 1985; Carsky and Masajo, 1991; Windmeijer and Andriesse, 1993; Hirose and Wakatsuki, 2002; Abe et al., 2007b, 2009a, 2009b), and water control is a primary key to rice production increase (JICA, 2003; Sakurai, 2006; Larson et al., 2010; Abe and Wakatsuki, 2011). Although Ishida et al. (1998) documented that *Baragi* was often used in case the farmers wanted to recultivate rice after the fallow based on their survey conducted only in the small part of the inland valley used by the Gadza village (close to Emitsun dadan in this study). However, our survey which included a wider area and other inland valley systems used by other villages revealed that Ishida et al. (1998)'s description seems to be an uncommon case in other parts of the study area. Moreover, Ishida et al. (1998) reported that Nupe farmers practice a sequence of land preparation methods rotated throughout the year that involved moving the soil; they often change land preparation methods between the rice cultivation in the main season and the off-season crop. However, the off-season crop was hardly observed in our studied villages, except in *Emitsun dandan*, and so its influence on land preparation for rice cultivation in the main season would be certainly limited.

The direct seeding practice in *Gbaragi* also helps rice avoid deep floods because the directly seeded rice becomes established earlier and matures earlier than transplanted rice, which may have growth delays from transplant injury (Farooq et al., 2011). These advantages were observed in *Gbaragi* and *Baragi* in our study. From these scientific viewpoints, the Nupe's farming practice is rational because the earlier crop establishment will enhance resistance against deep floods at the early vegetative stage of rice growth and the earlier maturity will be effective for reducing vulnerability to late-season drought. However, weed infestation is a major constraint in the direct-seeding method, and the cost of weed control is usually higher than in the transplanting method (Farooq et al., 2011). In this regard, however, our survey data showed that less and similar labor was respectively hired for the weeding in *Gbaragi* and *Baragi* than in *Togogi/Togoko kuru* and *Sawah*. The same trend was also found in the application rate of herbicide (Table 5). These unlikely results might be affected by the Nupe's management customs; most Nupe farmers weed the paddy plots three or four times only during for the rice growth period and seem not to care even if the rice fields are severely overtaken by weeds after the flowering stage.

In *Gbaragi* and *Baragi*, rice seeds were dibble-planted at a much lower plant density but a much higher number of seedlings per hill than in *Sawah* and *Togogi/Togoko kuru* (Table 3). This methodology of direct seeding is likely a risk management measure by the Nupe farmers. These practices were probably adopted to aim hedging the risk of plant loss due to animal (e.g., bird and rat) infestations and environmental hazards (e.g., drought and flood). *Gbaragi* showed no significant difference in number of seedlings per hill but had significantly lower plant density than *Baragi*. This suggests that the Nupe farmers use the same manner of direct seeding in spite of the substantial disparity in the land preparation measures and that the considerable difference in plant density simply arose from the different availabilities of planting spaces. Meanwhile, no significant difference was observed in either plant density or number of rice seedlings transplanted per hill in *Togogi/Togoko kuru* and *Sawah*, regardless of the disparity in the land surface smoothness and soil hardness (Fig. 2). Also, these two land preparation methods did not show any practical difference from one another in nursery making and seedling uploading. These results suggest that the mode of the transplanting was not affected by the introduction of the new land preparation method, i.e., *Sawah*. However, some farmers mentioned the advantage of *Sawah* in transplanting as the puddling by the power tiller made the surface soil very soft. *Sawah* was introduced to the study area very recently and may have some influence on the planting methods in the future through its local adaptation process.

As described above, *Gbaragi* and *Baragi* are considered a kind of labor-saving method as they require much less time for preparation than *Togogi/Togoko kuru* (Table 3). Furthermore, the direct-seeding practice with a lower plant density in *Gbaragi* and *Baragi* results in less time consumed by the planting work than in

Togogi/Togoko kuru and *Sawah*. It has been well acknowledged that the direct seeding method is faster, easier and less labor intensive than the transplanting method (Farooq et al., 2011). The more frequent appearance of *Gbaragi* reflects farmers' preference for the low labor requirement in addition to water control (Fig. 3). In contrast, Nupe farmers had to spend more time on the land preparation in *Togogi/Togoko kuru* because of mound construction and subsequent destruction prior to the transplanting, which required much more time than in *Gbaragi* and *Baragi*. Also, the practice of transplanting at a higher plant density called for more elaborate preparation of the land surface in *Togogi/Togoko kuru* compared to that for the direct-seeding method in *Gbaragi* and *Baragi*. For *Sawah*, land preparation was largely done with the help of the power tiller, and thus no manpower was demanded, except for the bund construction or rehabilitation. However, *Sawah* still required the same working time for nursery making, seedling uploading and transplanting as in *Togogi/Togoko kuru*[6)]. The mechanization in *Sawah* reduced the amount of labor devoted to land preparation and resulted in reduction of the total labor, to a similar level to that in *Baragi*. Yet, total labor was still significantly higher than in *Gbaragi*. This result highlights the labor-saving nature of *Gbaragi* in the Nupe's traditional system. To meet the labor requirement, more labor was hired for the land preparation in *Togogi/Togoko kuru* and for the transplanting in *Togogi/Togoko kuru* and *Sawah* than in *Gbaragi* and *Baragi* (Table 4). Ultimately, the higher demand for labor resulted in a higher cost for labor recruitment in *Togogi/Togoko kuru* and *Sawah* than in *Gbaragi* and *Baragi* (Table 6).

The Nupe farmers also carried out selective application of chemical fertilizers according to the land preparation method. In *Gbaragi* and *Baragi*, the Nupe farmers applied only marginal amounts of compound fertilizer and urea (Table 5). In contrast, these fertilizers were applied at a much higher rate in *Togogi/Togoko kuru* than in *Gbaragi* and *Baragi*. On a nitrogen basis, *Togogi/Togoko kuru* received twice as much nitrogen as *Gbaragi* and *Baragi*. This higher application rate of fertilizers was closely associated with the adoption rate of the improved variety in *Togogi/Togoko kuru* (Table 2). However, the Nupe farmers applied an intermediate amount of compound fertilizer and urea to *Sawah* without any significant difference from *Togogi/Togoko kuru* or from *Gbaragi* and *Baragi*. The same result was obtained for the nitrogen-based amount as well, in spite of the fact that *Sawah* recorded the highest rice yield. This finding confirmed the high productivity and nitrogen-use efficiency in *Sawah*, thanks to improved water control and better weed and soil fertility management (Wakatsuki et al. 2010; Abe and Wakatsuki, 2011).

The traditional labor-saving methods of rice cultivation, e.g., *Gbaragi* and *Baragi*, were associated with a low application rate of improved seeds and chemical fertilizers and low labor recruitment, resulting in a low production cost (Table 6). Accordingly, the rice yield, and thus the profit from the production sale, were also low in *Gbaragi* and *Baragi*, and the farmers obtained a marginal amount of income. These farming methods are representative of the low-input, low-output subsistence farming systems prevailing over sub-Saharan Africa. In contrast, the farmers spent the highest amount of production cost in *Togogi/Togoko kuru* due to the higher input of hired labor demanded by the improved method of land preparation and by rice transplanting and application of the largest amount of fertilizer along with the improved cultivars. As a result, rice yield was considerably improved in *Togogi/Togoko kuru*, and the associated gain in income was 1.5 to 2 times higher than in *Gbaragi* and *Baragi*. However, the highest income was obtained from *Sawah* because it produced the highest rice yield with moderate production costs. This resulted because the income generation in *Sawah* is much superior to that in the other land preparation methods, thanks to better water control and improved nutrient use efficiency in *Sawah*. Although *Sawah* enjoyed capital support from a local NGO which provided the farmers with the improved seeds and the power tiller service[7)], *Sawah* seems to have an advantage in income generation over the other land preparation methods even if these external supports cease in the future.

As mentioned above, *Gbaragi* and *Baragi* are mostly situated in the flood-prone valley bottom and on the drought-susceptible valley fringe, respectively, but *Togogi/Togoko kuru* and *Sawah* appear in between *Gbaragi* and *Baragi*. *Gbaragi* and *Baragi* have been established to suit the flood- and drought-prone environments, respectively, and have a certain advantages in risk management. Given the substantial risk for flood and drought, the Nupe farmers prepare the land by applying a minimum amount of labor and resource capital. In contrast, *Togogi/Togoko kuru* probably has been developed to improve rice productivity where there are relatively favorable conditions in terms of rice production. Where there are fewer and lesser environmental risks, the Nupe farmers preferentially use new technologies and input more labor and resource capital. The Nupe farmers have perceived that the yield potential of the improved varieties can be realized only in favorable production environments and that the traditional cultivars may be resistant against local environmental stresses because the farmers have selected them through repeated trials in their farmlands over the decades or centuries. The same is true for land preparation methods; the farmers cannot realize projected outcomes by introducing *Sawah* where the environment is unfavorable and may realize even negative outcomes if they do so. The farming strategy of Nupe farmers, i.e., selective adoption of new technologies along with application of land use methods and resource capital according to local environmental settings, may represent those of smallholder farmers in the transition from traditional to alternative systems in sub-Saharan Africa.

7. Conclusions and Policy Implications

The majority of the rural poor in sub-Saharan Africa are smallholder farmers who have been struggling with food insecurity, malnutrition and poverty in a harsh and resource-limited environment. Agriculture is a fundamental instrument for sustainable development and poverty reduction; agricultural development for economic growth requires a productivity revolution in smallholder farming (World Bank, 2007). So, it is worthwhile to understand the farming systems of smallholder farmers in transition from traditional to alternative systems.

Our findings in this study revealed the following farming strategies of the smallholder farmers:

- In favorable environmental conditions, the farmers preferentially try alternative farming systems that use new agricultural technologies and reasonable application of resource capital so that they obtain a higher benefit with less risk;

- In unfavorable environmental conditions, the farmers persist with traditional farming methods that use marginal input of resource capital in order to manage the higher risk, even though they receive a marginal economic return.

Success stories of boosts in food production have been increasingly reported in sub-Saharan Africa (Sanchez et al., 2009; Sanchez, 2010), but major areas of the region still remain unsuccessful (Otsuka, 2006; Otsuka and Kalirajan, 2006; Sasson, 2012). Our findings clearly suggest that any plans or projects for rural development involving technology adoption need to consider not only socioeconomic, institutional and political conditions but also local environmental settings. Alternative farming systems along with adoption of new technologies should be targeted to favorable environmental conditions by priority, while traditional agricultural systems' indigenous knowledge should be respected in unfavorable environments.

In the study region, a considerable portion of the paddy plots currently used for *Togogi/Togoko kuru* can be turned into *Sawah*, which has certain advantages in rice yield and economic return over the traditional methods. However, most lands under *Gbaragi* and *Baragi* would have low potential for *Sawah* installation because of high risks of flood and drought, unless a reliable irrigation scheme is developed over the inland valley watershed. Major constraints to realization of the remaining potential of *Sawah* development in the study region include the low availability of power tillers because of the high procurement cost (retail price in West Africa: US$3000–US$7000 per power tiller) due to high transaction cost, insufficient and unstable supply of improved seeds and limited access to chemical fertilizers in local markets. The government should work to eliminate these constraints in order to promote productivity improvement in wet rice cultivation, given that this is a major policy concern in Nigeria as well as in other West African countries (Seck et al., 2010; Wakatsuki et al., 2010; Abe and Wakatsuki, 2011).

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Notes

1) Inland valleys are defined as the upper reaches of river systems (Windmeijer and Andriesse, 1993). Eighty five million hectares of inland valley occupying 20% of the wetland area in tropical Africa (Andriesse, 1986) remain largely unexploited (> 90–80%) regardless of substantial potential for agricultural use. The Nupe call the inland valleys *fadama* (in Hausa) or *bata* (in Nupe).
2) Farmers listed more than 10 names for traditional rice varieties in the study area, e.g., modalisa, engbangichi and emigiradan. All varieties are *Oryza sativa* L. and *Oryza glaberrima* Steud. which sometimes occur in farmers' fields are regarded as a weed, and thus nobody reaps and eats it. Traditional varieties often have taller plant height, lower capacity for tillering, higher photosensitivity and a longer period for the maturity than improved varieties, e.g., WITA 4 (FARO44).
3) We found slightly different methodologies used in *Togogi/Togoko kuru* preparation between the Nasarafu and Shabamaliki areas and the Emitsu dandan and Ejeti areas. In general, Nupe farmers practice sequential land preparation methods with moving soils by

switching land preparation methods between the main season and the off-season for the purpose of weed control, soil fertility management and soil moisture retention (Ishida, 1997). However, in the Nassarafu, and Shabamaliki areas where off-season crop cultivation is not common and land preparation methods do not change in the dry season, Nupe farmers built *Ewako* within the basin (normally 200 to 250 mounds ha^{-1}) at the beginning of the rainy season and broke them down just before the transplanting in order to obtain a similar advantage through soil movement to that of changing land preparation methods. This method allows the surface soil to dry to a low moisture content and increases the soil's nitrogen availability derived from the death of soil microbes (Kyuma, 2004).

4) The plots given to the farmers in this trial were bunded basins; the operation did not include bund construction. Thus, the data requires careful interpretation.
5) Data on *Togogi/Togoko kuru* managed by the farmers in Shabamaraki were omitted from Fig. 7 because most of them are situated in a small depression on the higher slope of the inland valley, which has better water conditions than other places at a similar slope position.
6) The Nupe farmers also mentioned that there is no practical difference in nursery preparation and the transplanting method in *Togogi/Togoko kuru* and *Sawah*. Our field observation was also unable to find any remarkable differences in this regard.
7) The farmers are requested to pay the operating expenses of the power tillers such as fuel and an allowance for the operators, but they do not pay the procurement cost of the power tillers.

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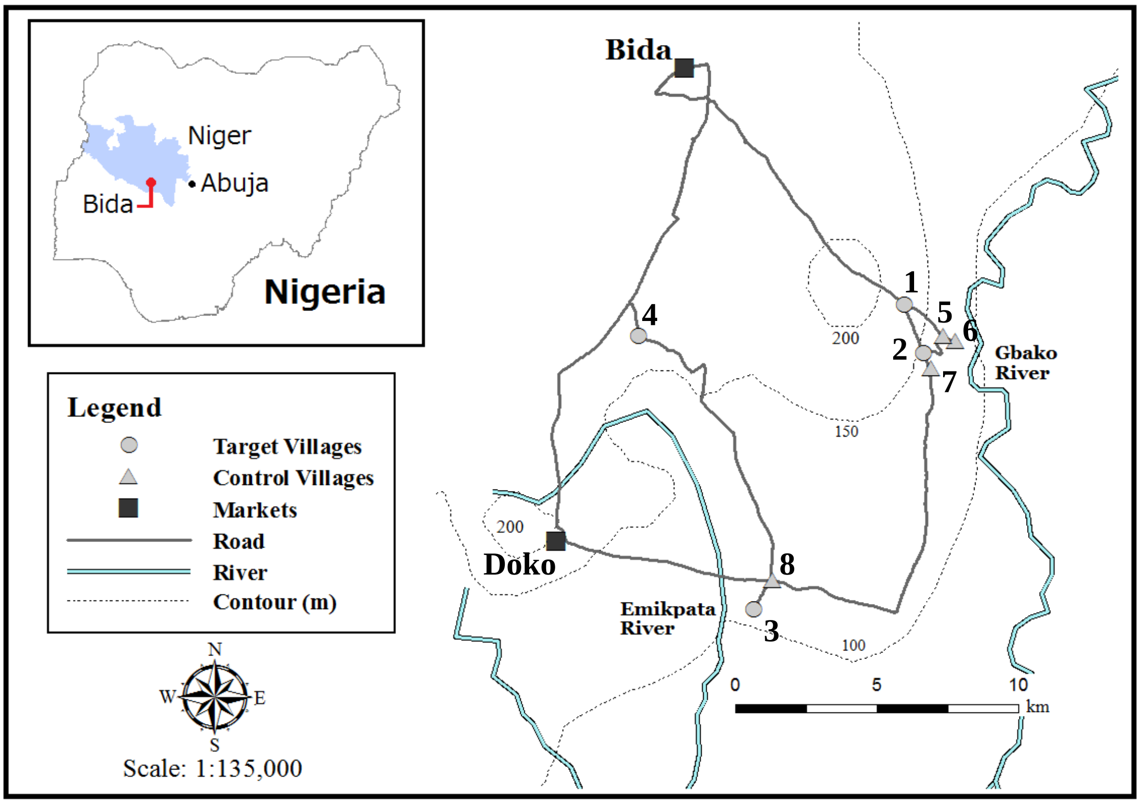

Figure 1: Study area and surveyed villages in this study

Village numbers indicate: 1. Shabamaliki, 2. Nassarafu, 3. Ejeti, 4. Emitsu dadan, 5. Tsuwatagi, 6. Emitsu, 7. Emiworogi and 8. Amgbasa.

Figure 2: Selected photographs of the paddy plots prepared using different land preparation methods in the study area

a: *Gbaragi*, b: *Toogogi/togoko kuru*, c: *Baragi*, d: *Sawah*

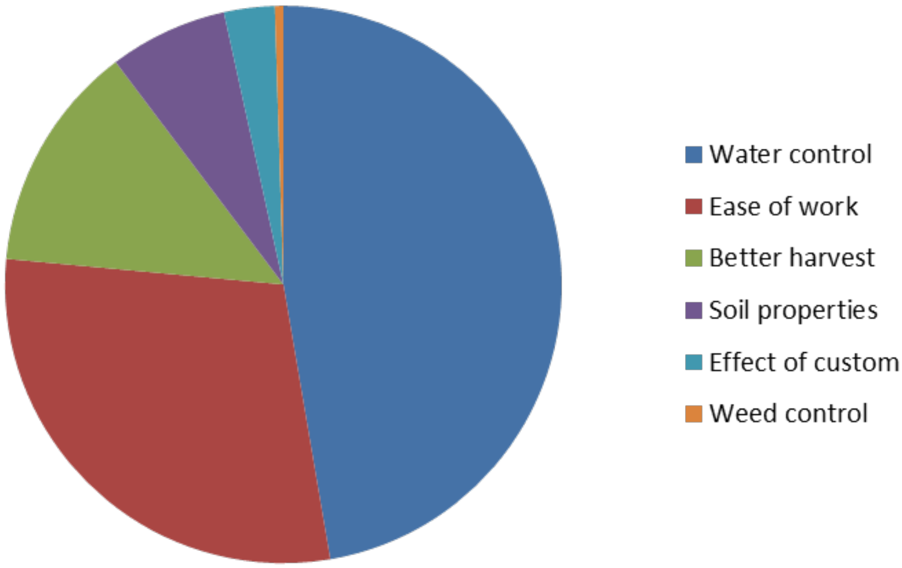

Figure 3: Reasons for the selection of land preparation methods for rice cultivation by Nupe farmers (plot *n* = 204)

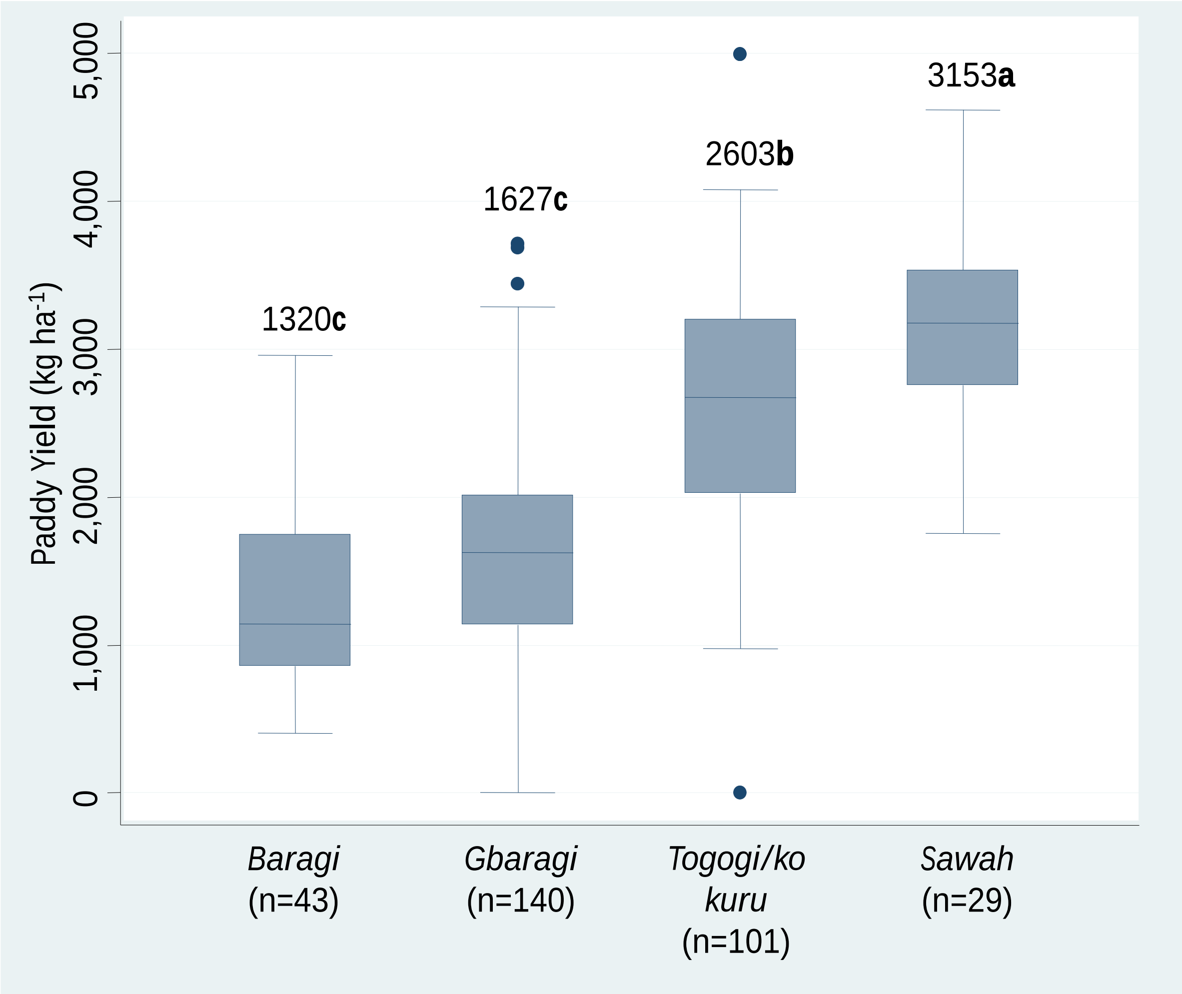

Figure 4: Paddy yield in the paddy plots prepared by different land preparation methods in the study area

In the box-and-whisker diagrams, bars in boxes, boxes, cross bars and closed circles indicate median value, range of 50% of the samples, maximum and minimum values and outliers, respectively. The numbers above the upper cross bars indicates mean values and are followed by different letters which denote significant difference at $P < 0.05$.

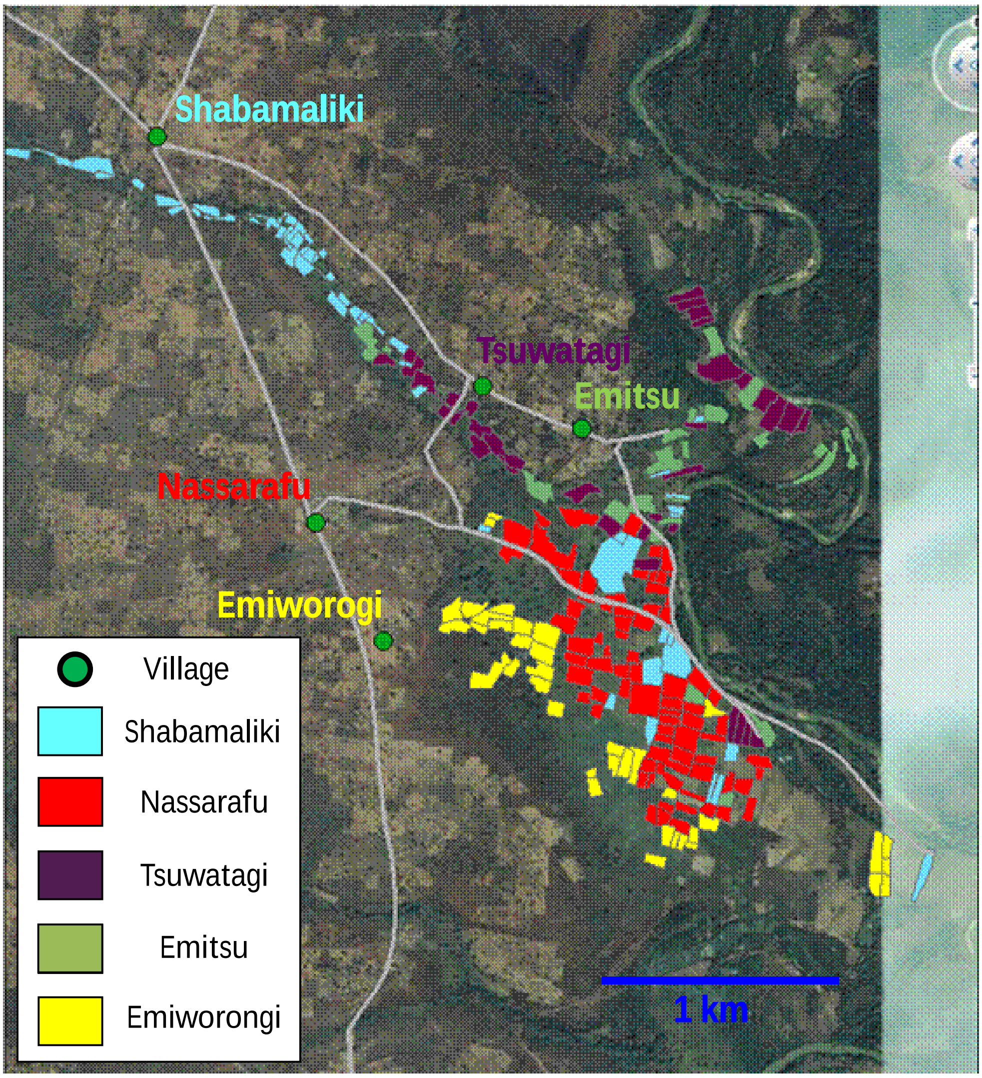

Figure 5: Geographic distribution of paddy plots managed by the farmers from different villages within the surveyed inland valley

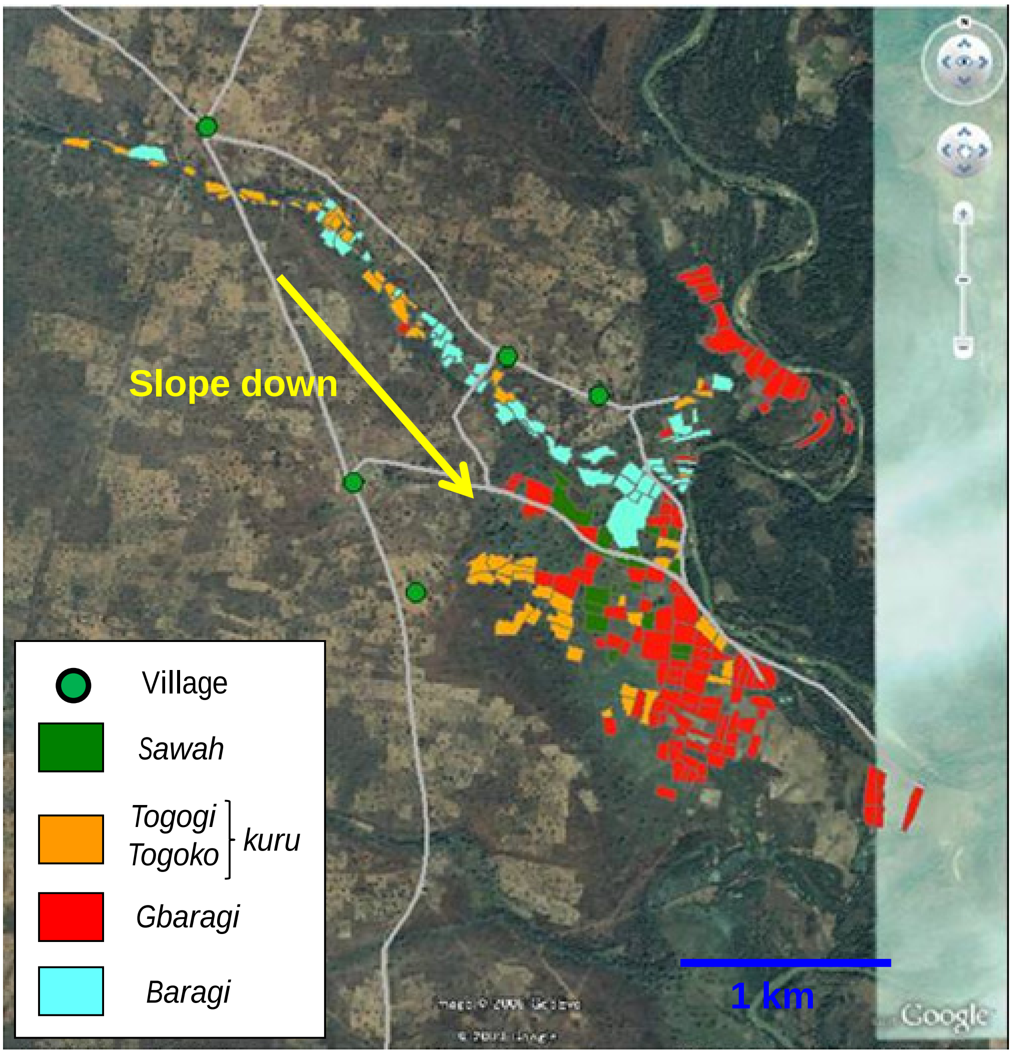

Figure 6: Geographic distribution of paddy plots prepared by different land preparation methods within the surveyed inland valley

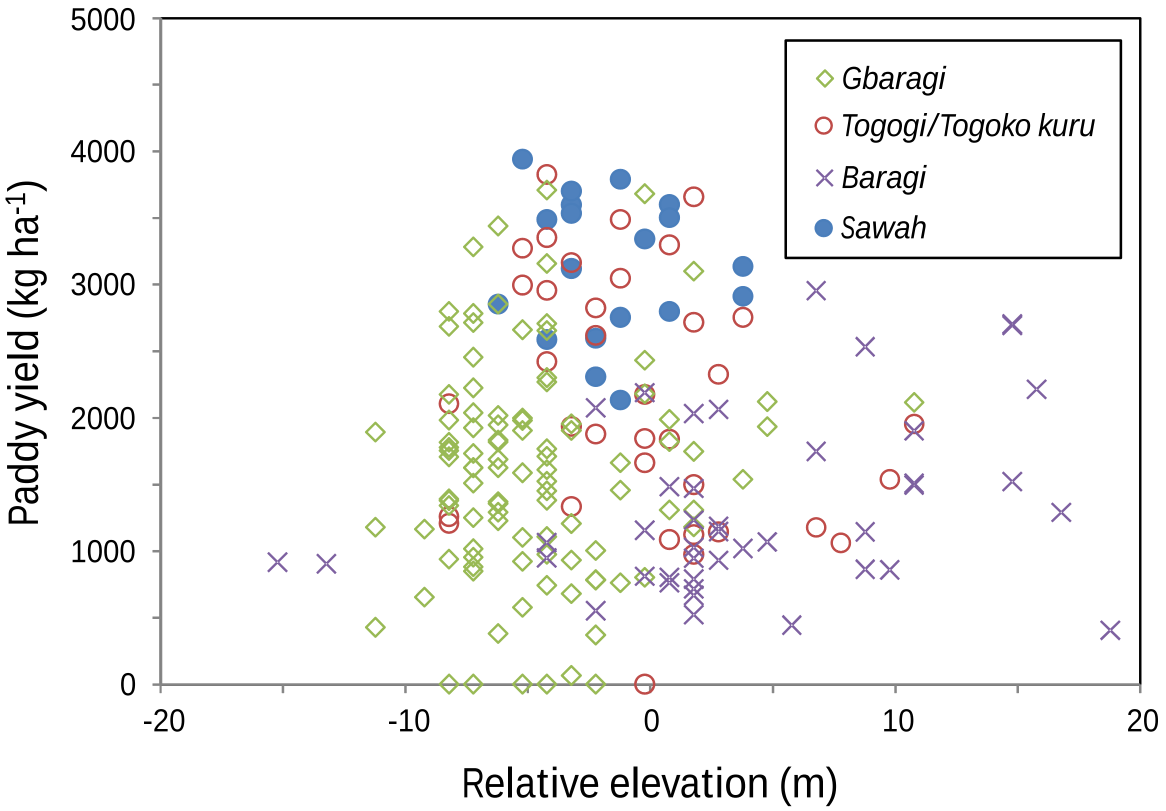

Figure 7: Geographic distribution of paddy plots prepared by different land preparation methods within the surveyed inland valley

Table 1: General characteristics of households and villages surveyed in this study

Village ID[†]	Village name	Number of interviewed household heads[‡]	Mean number of household members[§]	Mean area (ha) of rice fields tenanted by household head[§]	Mean distance (km) from the residence to the paddy fields[§]	Year of *sawah* introduction	Distance (km) to nearby market[††]
1	*Shabamaliki*	24 (92%)	14.0 (6.4)	0.84 (0.99)	1.49 (1.17)	2006	11.4 (Bida)
2	*Nassarafu*	19 (56%)	21.8 (16.5)	2.23 (1.21)	1.58 (0.33)	2004	13.2 (Bida)
3	*Ejeti*	24 (80%)	14.5 (6.5)	0,99 (0.67)	1.58 (2.28)	2001	7.4 (Doko)
4	*Emitsun dadan*	17 (81%)	10.4 (6.1)	0.28 (0.18)	1.71 (0.43)	2001	9.7 (Bida)
5	*Tsuwatagi*	9 (100%)	8.3 (3.2)	2.06 (0.75)	0.78 (0.55)	—	13.2 (Doko)
6	*Emitsu*	8 (100%)	13.1 (7.7)	1.50 (0.92)	0.70 (0.38)	—	13.6 (Doko)
7	*Emiworongi*	18 (95%)	11.7 (6.9)	1.09 (0.45)	1.11 (0.65)	—	13.8 (Bida)
8	*Amgbasa*	13 (93%)	13.4 (10.1)	1.06 (0.44)	6.70 (0.90)	—	7.8 (Doko)
—	Total	132 (82%)	13.9 (9.5)	1.17 (0.97)	1.65 (1.67)	—	11.3 (—)

[†] Village ID corresponds to that in Fig. 1.

[‡] The percentage of interviewed household heads to total number of household heads within the village is in parentheses.

[§] Standard deviation is in parentheses.

[††] The name of the nearby market is in parentheses.

Table 2: General characteristics of the paddy plots prepared by different land preparation methods in the study area

Land preparation type	Sample No.	Bunding	Leveling	Puddling	Village-plot distance (km)	Farm size (100 m^2)	Improved seed adoption (%)	Transplanting (%)
Sawah	29	good	fair	fair	1.08 (0.07)b	54.1 (8.5)a	96.6	100.0
Togogi/Togoko kuru	101	good	fair	none	0.98 (0.06)b	31.2 (2.3)b	94.1	100.0
Gbaragi	140	good	none	none	2.51 (0.18)a	59.3 (3.2)a	12.9	0.0
Baragi	43	poor	poor	none	0.82 (0.11)b	49.4 (8.8)ab	16.3	9.3
Total/Mean	313	—	—	—	1.65 (0.10)	48.4 (2.6)	36.5	42.8

Mean; standard error in parentheses.

Different letters followed by means in a row indicate significant differences ($P < 0.05$).

Table 3: Description of agronomic practices and labor requirements in different land preparation methods obtained in the farmer trial of this study

Land preparation type	Plant density (hill m^{-2})	Transplanting /sowing rate (seeds/seedlings hill^{-1})	Land preparation (min. plot^{-1})	Nursery preparation (min. nursery^{-1})	Seedlings uploading (min. nursery^{-1})	Transplanting /seeding (min. plot^{-1})	Total time (min. plot^{-1})
Sawah	10.0a	3.4b	00:00d	01:47	07:20	15:53a	24:59b
	(0.8)	(0.2)	(00:00)	(00:31)†	(02:42)†	(01:16)	(01:53)
Togogi/togoko	8.8a	3.4b	17:42a	01:47	07:20	19:04a	45:53a
kuru	(0.8)	(0.2)	(00:51)	(00:31)†	(02:42)†	(02:06)	(03:24)
Gbaragi	3.5b	16.4a	07:00c	N/A	N/A	06:32b	13:31c
	(0.3)	(1.2)	(00:27)			(00:40)	(01:01)
Baragi	5.8b	16.3a	09:15b	N/A	N/A	08:36b	17:51bc
	(0.4)	(1.3)	(00:29)			(00:40)	(01:00)
Mean	7.0	9.9	08:29	N/A	N/A	12:31	25:34
	(0.4)	(0.9)	(00:52)			(00:56)	(01:55)

Min:sec on average; standard error is in parentheses.
Different letters followed by means in a row indicate significant differences ($P < 0.05$).
† indicates standard deviation.

Table 4: Amount of labor (man day ha^{-1}) hired for different land preparation methods in this study

	Land preparation	Transplanting	Weeding	Harvesting	Total
Sawah	19.0b	46.2a	7.5ab	7.6b	80.3b
	(2.4)	(11.8)	(2.5)	(1.6)	(15.6)
Togogi/Togoko	44.4a	48.2a	15.7a	25.3a	133.6a
kuru	(3.9)	(4.8)	(2.1)	(3.7)	(11.0)
Gbaragi	25.4b	0.0b	11.7ab	13.8b	50.9b
	(1.8)	(0.0)	(1.3)	(1.6)	(4.2)
Baragi	28.2b	2.2b	6.4b	11.4b	48.1b
	(4.7)	(1.1)	(1.1)	(1.8)	(6.4)
Mean	31.3	20.1	11.9	16.6	79.9
	(1.7)	(2.3)	(0.9)	(1.5)	(4.8)

Mean; standard error in parentheses.

Different letters followed by means in a row indicate significant differences ($P < 0.05$).

Table 5: Resource input in paddy plots prepared by different land preparation methods in the study area

	NPK (kg ha^{-1})	Urea (kg ha^{-1})	Total N applied (kg ha^{-1})	Herbicide (L ha^{-1})
Sawah	203.4ab	62.9ab	49.3ab	2.8ab
	(40.4)	(17.7)	(9.1)	(0.4)
Togogi/Togoko	275.0a	128.5a	86.6a	4.3a
kuru	(37.0)	(25.5)	(11.9)	(0.4)
Gbaragi	92.2b	58.8b	36.3b	3.3ab
	(11.2)	(10.4)	(5.0)	(0.2)
Baragi	100.5b	55.4ab	35.5b	2.3b
	(27.8)	(16.0)	(8.1)	(0.3)
Mean total	162.6	81.2	53.6	3.4
	(14.7)	(10.0)	(4.8)	(0.2)

Mean; standard error in parentheses.

Different letters followed by means in a row indicate significant differences ($P < 0.05$).

Table 6: Economic characteristics (in US dollars ha^{-1}) of rice production in the paddy plots prepared by different land preparation methods in this study

	Income	Gain	Hired labor	Fertilizer	Seed	Herbicide	Power tiller	Total cost
Sawah	981.5a	1405.0a	255.4ab	125.3ab	0.0b	13.1ab	29.6a	423.5a
	(83.5)	(51.9)	(52.4)	(24.0)	(0.0)	(2.1)	(6.4)	(71.2)
Togogi/Togoko	642.4b	1168.2b	302.4a	183.6a	29.2a	10.6b	0.0b	525.8a
kuru	(46.5)	(42.7)	(24.8)	(21.0)	(5.3)	(1.1)	(0.0)	(37.2)
Gbaragi	492.7c	736.3c	148.0bc	66.7b	12.5b	16.5a	0.0b	243.6b
	(26.7)	(30.6)	(13.0)	(7.7)	(3.1)	(1.2)	(0.0)	(19.0)
Baragi	374.8c	579.3c	100.6c	65.3b	29.2ab	9.4b	0.0b	204.5b
	(35.0)	(48.6)	(12.5)	(14.9)	(10.0)	(1.6)	(0.0)	(26.2)
Mean	570.1	916.0	201.3	109.6	19.0	13.3	1.0	345,9
	(23.0)	(26.0)	(12.0)	(8.7)	(2.7)	(0.7)	(0.3)	(18.1)

Mean; standard error in parentheses.

Different letters followed by means in a row indicate significant differences ($P < 0.05$).

Exchange rate: US$1.00 = 116.91 Nigerian Naira