How Promising Is the Rice Green Revolution in Sub-Saharan Africa? - Evidence from Case Studies in Mozambique, Tanzania, Uganda, and Ghana[1]

Keijiro Otsuka

1. Introduction

While the population continues to grow rapidly, the pace of area expansion has slowed down considerably in sub-Saharan Africa (SSA) due to the gradual exhaustion of uncultivated areas. On average, cultivated land per farming population has declined by about 40% since the 1960s and value added per worker now averages around 12% below 1980 levels. Investments in the development of new technologies have declined in recent years even though their adoption rates are low compared to other regions. In order to reduce widespread and persistent rural poverty in SSA, it is imperative to increase food production by increasing the productivity per unit of land.

We believe that what is urgently needed in SSA is a Green Revolution, which has successfully increased rice and wheat yields in tropical Asia over the last several decades. In Asia, small farmers actively adopted new improved technologies (David and Otsuka 1994), and there is no reason to assume that small farmers in SSA will not adopt new profitable technologies (Otsuka 2006; Otsuka and Kijima 2010). Yet the appropriate strategies to realize a Green Revolution in SSA are still unclear. Recent studies edited by Otsuka and Larson (2013), which compare the experience of the Asian Green Revolution with current grain farming in SSA, suggest that lowland rice is the most promising grain. This is essentially because high-yielding rice technology can be directly

1. This is a result of a research project being conducted at JICA Research Institute to empirically analyze how best the CARD initiative (See Chapter 2, Section 3) can serve to increase rice productivity and reduce poverty. I am heavily indebted to its members, namely Yoko Kijima, Kei Kajisa, Yuko Nakano, and Takeshi Sakurai. I would also like to thank JICA Research Institute for the intellectual and financial support it provided for this project.

transferable from tropical Asia to SSA (Estudillo and Otsuka 2012; Nakano et al. 2012).

This is illustrated by Figure 1, which compares changes in grain yields over time in India and SSA and their differences between the two regions. India is chosen for comparison because among Asian countries India is agro-climatically similar to SSA and, hence, cropping patterns are not so different (Tsusaka and Otsuka 2013a, 2013b).[2] Several important observations can be made. Firstly, grain yields were generally similar between India and SSA in the early 1960s before the Green Revolution began, which indicates that the difference in agro-climatic conditions alone cannot explain the large yield difference between the two regions at present. Secondly, the yields of sorghum and millet did not increase much even in India and the yield gap between the two regions is nil, which suggests that the potential of a Green Revolution in these crops is limited in SSA. Thirdly, the current yield gap is substantial in the case of wheat and rice, even though their yields increased appreciably in SSA. Since wheat can be produced primarily in a temperate zone, its potential production area is more limited than rice in SSA due to the dominance of a tropical climate. Thus, rice is likely to be critically important for the expansion of grain production in SSA. Furthermore, rice consumption has been increasing dramatically in this region in the past few decades. Lastly, the yield gap is only modest in maize, even though maize is the most important crop in SSA in both production and consumption. It is likely that the productivity gain in the maize sector in SSA from a technology transfer from Asia will not be large.

Although rice looks a promising crop from the aggregate data, micro-level evidence is needed to substantiate the argument that rice is the most promising crop in SSA. The first purpose of this study is to analyze the potential of a rice Green Revolution in SSA based on recently completed cases studies of rice-growing households in Mozambique, Tanzania, Uganda, and Ghana.[3] The second purpose is to draw up the

2. For example, sorghum and millet are grown in many countries in SSA but primarily in India in Asia. Analytically, however, a comparison between tropical Asia as a whole and SSA does not lead to major changes in our discussion (Estudillo and Otsuka 2012).

3. Senegal is also included in this project but the data collection has been delayed, so its analytical results will be reported later. Note, however, that according to our preliminary survey, the average irrigated rice yield in the Senegal River basin exceeds 5 tons per hectare, which is comparable to the irrigated yields in Asia.

implications of an effective strategy for a rice Green Revolution in SSA. We believe that, if successful, a rice Green Revolution can be a role model for Green Revolutions in other grains, particularly in maize production.

2. Is Asian Rice Technology Transferable to SSA?

Asian rice technology. Although the rice yield is still low in SSA, we should not overlook the fact that it has increased from 1.25 tons per hectare in the early 1960s to 1.8 tons per hectare in the late 2000s. In tropical Asia where lowland rice production dominates, the rice yield before the Green Revolution was 1.5 tons per hectare (see Figure 1).[4] Also, note that half of the rice area in SSA is upland, where the yield is substantially lower than in lowland paddy fields (Balasubramanian et al. 2007). Thus, it seems reasonable to assume that if new technology is not introduced and production is carried out under rain-fed conditions, the lowland paddy yield will range from 1.0 to 1.5 tons per hectare. We also hypothesize that the average rice yield has increased in SSA primarily due to the introduction of Asian-type improved rice technology.[5]

We focus on lowland rice, not upland rice, primarily because the prospect for a large improvement of the yield is much greater for lowland rice than upland rice. We also did not encounter upland rice, such as NERICA (new rice for Africa), in our study sites except in Uganda. Kijima et al. (2006, 2008, 2011) found that NERICA is potentially high-yielding but sensitive to rainfall and that the rate of discontinuation of NERICA adoption is also high, indicating that NERICA was grown in unsuitable areas or that sustainable management was not well understood by farmers. Also, the NERICA yield is exceptionally high in Uganda compared with other countries in SSA (Otsuka and Larson 2013). The tentative conclusion of this study is that upland rice is not particularly promising, even though there were great expectations for the impact of NERICA on the upland rice yield.

The Green Revolution in Asia is alternatively called the seed-fertilizer revolution because the engine of growth was the development and

4. Nearly half of the paddy fields were irrigated in Asia but the difference in yield between rain-fed and irrigated areas was not large before the advent of MVs.

5. This is consistent with the results of a review of rice farming in SSA by Balasubramanian et al. (2007).

diffusion of fertilizer-responsive, high-yielding modern varieties (MVs) of lowland rice (David and Otsuka 1994). It is also important to realize that paddy fields were bunded and leveled almost without exception in Asia when the rice Green Revolution began.[6] Bunding is needed to store water in the paddy fields to reduce weed growth, whereas leveling is necessary for even growth of rice plants and germination of directly broadcasted seeds. In other words, these production practices are essential for water and weed control and healthy growth of lowland rice plants. Draft animals or tractors are usually used for bunding and leveling, but they are often not used in SSA, as will be shown shortly. No less important than these production practices is straight-row transplanting, which provides space for weeding. Instead of transplanting, direct seeding can be adopted without sacrificing yield if paddy fields are bunded and leveled well and if herbicide is used. Herbicide, however, may not be available or may be too expensive, even if available in SSA. In the African setting, direct seeding is not generally recommended and transplanting is the generally preferred option. A major contribution of this study is to establish that these improved production practices are highly complementary to improved seed-fertilizer technology.

The case of Mozambique. Table 1 compares yields and production practices across rain-fed and irrigated areas in Mozambique (Kajisa and Payongayong 2011a, 2011b). Thirty-three villages in 9 districts in Zambezia and Sofara provinces in the Central region are chosen as representative rain-fed areas in this country, whereas the Chokwe irrigation scheme in the southern region is chosen as the irrigated study site. As in other countries in SSA, the irrigated area accounts for a small proportion of paddy area in this country. Furthermore, MVs are seldom adopted, chemical fertilizer is not used, and animal and tractor use is nil in rain-fed areas. Under such conditions, the rice yield is very low and unstable with the average being a mere 1.1 tons per hectare, which is consistent with our expectations. The yield per hectare is not very high in the Chokwe irrigation scheme either, mainly because the irrigation facilities are not well maintained. In fact, the top 20% of farmers, who receive adequate water, adopt MVs, and apply fertilizer, achieve a rate as high as 3.9 tons per hectare. Note that popular MVs are old MVs

6. There is no clear evidence on the prevalence of bunding and leveling in paddy fields in Asia in the 1960s and 1970s. My argument is based on interviews with rice scientists who worked in Asia in the 1970s.

developed in Nigeria (ITA312) in the late 1970s by crossing Asian MVs and African local varieties.[7] This clearly shows that there has been no attempt to transfer new Asian-type varieties to Mozambique. The yield could be higher if more modern improved MVs had been disseminated in Chokwe.

The case of Tanzania. The case of Tanzania is more revealing (Table 2). The three major rice growing districts with distinctly different production environments were chosen for this study. First, the average yield in rain-fed areas ranges from 1.6 tons per hectare in the Shinyanga region to 2.0 tons per hectare in the Morogoro region, which is much higher than in rain-fed areas in Mozambique. This relatively high yield in rain-fed areas in Tanzania can be attributed, at least partly, to some adoption of MVs, some chemical fertilizer application, and the adoption of some improved production practices. Second, the yields are considerably higher in irrigated areas. The adoption rate of MVs is very high in the Morogoro region, whereas chemical fertilizer use is high in the Morogoro and Mbeya regions. Note that there is no tradition of rice production in Tanzania, so even "traditional varieties" are imported improved varieties from abroad. This would explain why the yield is as high as 4.6 tons per hectare under irrigated conditions in the Shinyanga region, even though the adoption rate of MVs is very low. Third, the adoption rates of bunding and leveling are close to 100% in irrigated areas, which seems to help explain the considerably high yields in irrigated areas in Tanzania. Thus, it is clear that a combination of improved seeds, improved production practices, and irrigation leads to significantly high yields, resulting in a "mini" Green Revolution in this country.

The case of Uganda. The importance of improved production practices can also be clearly seen from the case study of basically rain-fed areas in the Eastern Region in Uganda (see Table 3), as reported by Kijima, Ito, and Otsuka (2011, 2012). Note that Bugiri and Mayuge were sites of a participatory rice training program offered by JICA, whereas no such training was offered in Bukedea and Pallisa. Also note that the demonstration of a simple irrigation scheme was implemented only in Bugiri. Roughly speaking, the difference between Bugiri and Mayuge is due primarily to the presence of irrigation in the former, whereas a major

7. To our surprise, C4, which was developed in the early 1960s by the University of the Philippines, Los Banos, was adopted in 22% of the paddy fields in Chokwe.

part of the difference between Burigi-cum-Mayuge and Bekedea-cum-Palissa is due mainly to the implementation of a rice training program in the former areas, even though some yield differences can be attributed to differences in agro-climate. In Bugiri, where Asian-type MVs are adopted in more than 40% of paddy fields, the yield and the number of improved production practices adopted are positively correlated, indicating that MVs and improved production practices are complementary. Considering that chemical fertilizer is not applied in Uganda, the yield of more than 4 tons per hectare is impressively high, indicating the high potential of rice yields in this country due to relatively high precipitation and fertile soil. It is likely, however, that such high yield is unsustainable, unless fertilizer is applied to maintain soil fertility.[8] The yield in Mayuge is reasonably high if all four improved production practices are adopted. In contrast, the yields are much lower and variable regardless of the adoption of improved practices in Bekedea and Palissa. Even if improved production practices are adopted, whether they are adopted properly can be questioned, as these areas were not covered by the training program. The average yield in these two sites is 1.8 tons per hectare, which is not low compared with other rain-fed areas in SSA. A critically important finding of the Uganda case study is that the rice training program encouraged the adoption of improved production practices and improved the profitability of rice farming (Kijima, Ito, and Otsuka 2012).

It must be pointed out that the rain-fed area in Uganda is located at the bottom of a valley. Although it is rain-fed, its production environment is favorable for lowland rice production, because the soil is fertile and moist. In my observations, such production environments are abundant in SSA, and most have been unused until recently. Probably for rice production such rain-fed area is more favorable than rain-fed areas in Asia, most of which are located in flat areas. The Northern Region in Ghana is another example of a rain-fed area at the bottom of a valley with mild slopes, which has huge potential to increase rice production.

8. In the Doho irrigation scheme located in the Easter Region, the rice yield is about 3 tons per hectare, even though double cropping of rice has been practiced for a few decades without chemical fertilizer (Nakano and Otsuka 2011).

The case of Ghana. The case study in Northern Ghana is unique in that it compares the rice farming performance between villages where the Lowland Rice Development Project (LRDP) was implemented and villages where no such project was implemented (deGraft-Johnson et al. 2012). Twenty project villages and 40 non-project villages were selected randomly for this study and in each village 20 rice-farming households were surveyed.[9] Out of 40 non-project villages, 20 are located within a 20-kilometer radius of any of the project villages and the other 20 are located beyond the 20-kilometer radius. The former are called "nearby villages" and the latter "remote villages." The LRDP, which was implemented from 1998 to 2003, was designed to promote the dissemination of MVs, chemical fertilizer use, bunding, leveling, and dibbling.[10] Aside from the practice of dibbling, the four technologies are essential components of Asian Green Revolution technology. Thus, in a sense, the purpose of LRDP was to transfer Asian Green Revolution technology to SSA. Transplanting was not recommended because this area suffers from floods and seedlings cannot survive under submerged conditions.

According to Figure 2, improved technologies were seldom adopted before the implementation of the LRDP. During the LRDP implementation period they were adopted primarily in the project villages, whereas they were diffused to nearby villages after the LRDP period, suggesting technology spillovers from the project to other villages. The adoption rates of new technologies are generally low in remote villages.[11] It is clear that the adoption rates of both MVs and chemical fertilizer are equally high, which indicates the strong complementarity between fertilizer-responsive MVs and fertilizer. Leveling is adopted by about half of the sample farmers at present, whereas bunding and dibbling are not widely adopted. Another important observation is that the rate of dis-adoption, i.e., adoption in the past but discontinuation later, is high for dibbling. According to our respondents, dibbling is highly labor-intensive, and this is the major reason for dis-adoption. Thus, we suspect that dibbling may not be appropriate technology in this region.

9. Reliable data were obtained from 545 households.

10. Dibbling is a crop establishment method in which seeds are planted in holes created by sticks. Dibbling is not needed, if paddy fields are well bunded and leveled so that broadcasted seeds are germinated well.

11. Socio-economic conditions are very similar between the project and nearby villages, whereas the remote villages are far from the capital city and endowed with large land areas.

Table 4 summarizes the technology adoption, paddy yield, labor use, and the factor share of labor. It is clear that the rice yield is lowest among non-adopters of new technology, which is 1.5 tons per hectare and falls in the expected range under rain-fed conditions without new technologies. The yield becomes higher as larger amounts of new technologies are adopted. It is interesting to observe that an average yield of 2.6 tons per hectare among full-package technology adopters is almost identical to the average lowland rice yield under rain-fed conditions in Asia in the late 1980s reported by David and Otsuka (1994). This indicates that the yield potential under rain-fed condition in SSA is not inferior to that in tropical Asia. While it is true that labor use per hectare becomes larger with increases in the adoption of new technologies, the factor share of labor tends to decline, which indicates that new technologies are not labor-using.

In sum, our case studies demonstrate large potentials to increase rice yields in SSA by disseminating Asian Green Revolution technology. Although we did not discuss in detail in this article, our case studies indicate that new technologies are not only productive but also profitable. In short, Asian rice Green Revolution technology is directly transferable to SSA.

3. Key Questions

Before recommending further dissemination of new technologies, we must ask a few key questions. The first question is whether the benefit of new technologies accrues to small farmers. If these new technologies are adopted primarily by large farmers, their contribution to poverty reduction is limited, because it is small farmers who suffer from poverty (Yamano, Otsuka, and Place 2011). The second question is what the major constraints are on the adoption of new technologies. In order to disseminate new technologies to wide areas, we have to remove such constraints.

Commonly our case studies do not find any significantly positive effect of farm size on technology adoption. In the case of Ghana, it has a negative and significant effect on the adoption of dibbling, which is highly labor-intensive. In both irrigated and rain-fed areas in Mozambique (Kajisa and Payongayong 2011a, 2011b) and Uganda

(Kijima, Ito, and Otsuka 2011), the effects of farm size on paddy yields are found to be negative, implying that the yield per hectare is higher on smaller farms. These findings are consistent with the negative correlation between farm size and yield widely observed in SSA recently (Larson et al. 2012), which can be explained by the higher intensity of family labor on smaller farms.[12] While the effect of farm size on rice income per hectare is negative and significant in Tanzania (Nakano and Kajisa 2012), no effect on profit is found in Uganda and Ghana (Kijima, Ito, and Otsuka 2012; deGraft-Johnson et al. 2012). Thus, there is no evidence that new rice technologies particularly favor large farms. On the contrary, they seem to be conducive to equitable distribution of income in rural communities in SSA by offering expanded work opportunities for family labor, which is a major resource of poor small farmers. This is consistent with the observations in Asia that the impacts of the rice Green Revolution technology are neutral with respect to farm size (David and Otsuka 1994).

While irrigation is found to be an important determinant of rice yield, there is no evidence that it is necessary for the adoption of new technology. Considering that rain-fed areas dominate in SSA, a critically significant finding of this study is that the improved rice technologies have significant impacts on the rice yields under rain-fed conditions. Judging from the results of studies in the rain-fed areas of Uganda and Ghana (Tables 3 and 4), it seems possible to increase rice yield by 50 to 100% by adopting the improved technologies. In order to increase the rice yield much further, irrigation is needed. Whether irrigation investment pays is an important issue to be examined carefully.

The finding that training activities with demonstration plots are effective in the dissemination of the new rice technologies in Uganda and Ghana suggests that a major constraint on the wider adoption of the new technologies is the farmers' lack of knowledge on new technologies. According to the case study in Ghana (deGraft-Johnson et al. 2012), the spillover effects of new technology adoption in the project villages on the adoption in non-project villages are significant in the case of bunding and leveling but not in the case of MVs and fertilizer applications. The authors argue that this is due to the fact that while the bunding and

12. Monitoring of hired labor in a spatially wide environment in agriculture is costly, so that the endowment of family labor relative to farm size is the critical determinant of crop yield (Hayami and Otsuka 1993).

leveling are visible and imitable, the know-how on appropriate cultivation of MVs with fertilizer cannot be easily copied. If this is true, it may be a good idea to set up a relatively small number of demonstration plots compared with the number of locations where training programs are offered.

Kijima et al. (2011) find that the dis-adoption rate of NERICA is very high (i.e., in the vicinity of 50%). This is either because NERICA was disseminated to unsuitable areas for production or because sustainable management was not well understood by farmers. Indeed, there is the indication that yields of NERICA decline over time due to the deterioration of self-produced seeds or soil quality. In either case, the major problem is that appropriate production knowledge of NERICA was not disseminated to rice farmers.

It is clear that the absence of an effective extension system is a major constraint on the rice Green Revolution in SSA. In Ghana, even though the LRDP was an effective program, similar programs have not been implemented for nearly 10 years. In Uganda, the geographical coverage of the training program is very small. It is worse in Mozambique where no extension program for rice farming has been carried out. Actually, there are a very small number of agricultural extension workers in SSA. Furthermore, only a few of them are knowledgeable about rice farming. Unless we invest in the capacity building of extension workers, the target of CARD (Coalition for African Rice Development), that is the doubling of rice production in ten years from 2008, may not be achieved.

Another possible constraint on technology adoption is the lack of credit. Kajisa and Payongayong (2011) argue that the lack of credit access leads to the insufficient application of chemical fertilizer as well as hired labor use in the Chokwe irrigation scheme in Mozambique. Similarly, Nakano and Kajisa (2011) report that the access to formal credit is an important determinant of fertilizer use, but not MV adoption in Tanzania. MV seeds can be self-produced and, hence, credit access is unlikely to be important in MV adoption. While improving access to credit is likely to be important to increase fertilizer application, it is also remarkable to realize that considerably high rice yields are achieved without functioning credit markets in our four study sites. Therefore, it seems fair to conclude that improved credit access is desirable but not essential for the improvement of rice yields in SSA. Furthermore, according to our ongoing research in the Mwea irrigation scheme in Kenya, which is a large irrigation scheme consisting of 12,000 hectares with well-maintained facilities, rice yields are as high as 5 to 7 tons per hectare and credits are supplied not only by agricultural cooperatives but also by rice traders, as in many rice growing areas in Asia. It may well be that large demand for fertilizer induces the development of informal credit markets, where standing crops serve as the role of credit.

4. Concluding Remarks

The four case studies we have reviewed in this article clearly demonstrate that in order to realize the rice Green Revolution in SSA, high-yielding MV seeds, application of fertilizer, and the adoption of bunding and leveling are essential. We found that very high yields are realized in some irrigated areas in Tanzania and Uganda and reasonably high yields are achieved in some rain-fed areas in Tanzania, Uganda, and Ghana. Commonly in these areas, Asian type-MVs as well as bunding and leveling practices are adopted. These findings indicate that Asian rice technology can be *directly* transferable to SSA.[13] On the other hand, there are many areas in SSA where unimproved varieties are adopted, chemical fertilizer is not used, and paddy fields are not bunded and leveled. In such areas, the rice yield is low and ranges from 1.0 to 1.5 tons per hectare, which is close to rice yields in Asia before the Green Revolution. These observations strongly indicate that a strategic priority on the capacity building of extension specialists on rice and strengthening extension activities for rice production will be warranted, in order to realize a rice Green Revolution in SSA.

So far, however, inadequate resources have been allocated to the capacity building and extension. Unless more resources are allocated to these activities, the efforts to realize a rice Green Revolution in SSA are bound to fail.

Since MVs are fertilizer-responsive, once they are adopted, demand for fertilizer will increase, which, in turn, will increase the demand for credit. Similarly, since MVs are more productive under irrigated conditions, adoption of MVs will increase the demand for irrigation

13. Asian varieties, however, are susceptible to yellow mottle virus, which is unique to SSA. Thus, MVs tolerant to this virus must be developed urgently (Balasubramanian et al. 2007).

water. Thus, the benefit and cost of credit programs and irrigation projects must be carefully reassessed, while considering the large expected gains in productivity and profitability of rice farming in SSA.

We have been conducting research on lowland rice production partly because it is the most promising crop and partly because the success of the developing rice sector in SSA can provide a model for a successful Green Revolution in SSA. According to Otsuka and Larson (2013), profitable and productive maize technology is yet to be established. Indeed, although maize is the single most important crop in SSA, we seldom observed impressively high maize yields anywhere in SSA. It seems to us that the prerequisite for a maize Green Revolution is the development of truly profitable and productive maize seeds and farming practices for this crop. Once such technology is developed, it will trigger the change towards the maize Green Revolution in SSA. It is our hope that successful development of the rice sector can be a role model of the Green Revolution in other crops in this region.

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Table 1. Paddy yields and production practices in Mozambique

	Chokwe irrigation scheme	Rain-fed areas in central region		
		Bottom 1/3	Middle 1/3	Top 1/3
Yield per ha (tons)	2.1	0.3	0.8	2.2
Use of MVs (%)	92	0.0	0.0	3.0
Fertilizer use (%)	52	0.0	0.0	0.0
Plots with bund (%)	100	52	41	43
Animal use (%)	48	0	2	5
Tractor use (%)	55	2	5	2
No. of sample households	176	66	66	65

Table 2. Rice yields, the use of modern inputs and improved production practices by region and irrigation status in Tanzania

	Morogoro		Mbeya		Shinyanga	
	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated
Paddy yields (t/ha)	2.0	3.8	1.6	3.5	1.7	4.6
Modern inputs use						
Share of modern varieties (%)	17.8	87.5	0.0	2.1	1.9	13.1
Chemical fertilizer use (kg/ha)	11.7	40.4	10.7	31.7	0.9	0.0
Improved practices						
Share of bunded plots (%)	8.2	84.8	16.3	89.6	95.3	100.0
Share of leveled plots (%)	22.0	69.6	38.5	78.1	87.6	100.0
Share of straight row transplanting plots	4.4	47.8	3.8	22.9	6.4	0.0
No. of sample households	182	46	104	96	234	10

Table 3. Rice yields (ton/ha) according to the cultivation practices adopted in September 2008 – August 2009 in Uganda [a]

	All	Bugiri	Mayuge	Bukedea	Pallisa
4 practices	4.13	4.47	2.89	1.22	0.37
3 practices	3.20	4.15	1.89	---	1.54
2 practices	2.25	3.07	2.00	3.95	2.26
1 practice	1.81	2.30	1.91	1.89	1.38
Non-adopters	1.33	---	0.79 [b]	1.42	0.66 [c]
Fertilizer use	7.55c	7.55 [d]	---	---	---
Adoption of MVs (%)	19.6	43.8	40.0	5.0	1.6
No. of sample households	300	75	75	75	75

a. The numbers show the means for the rice yield in tons per hectare. The adoption of 4 practices means bunding, leveling, proper timing of transplanting, and straight-row planting.
b. Only 1 observation.
c. Only 3 observations.
d. Only 4 observations.

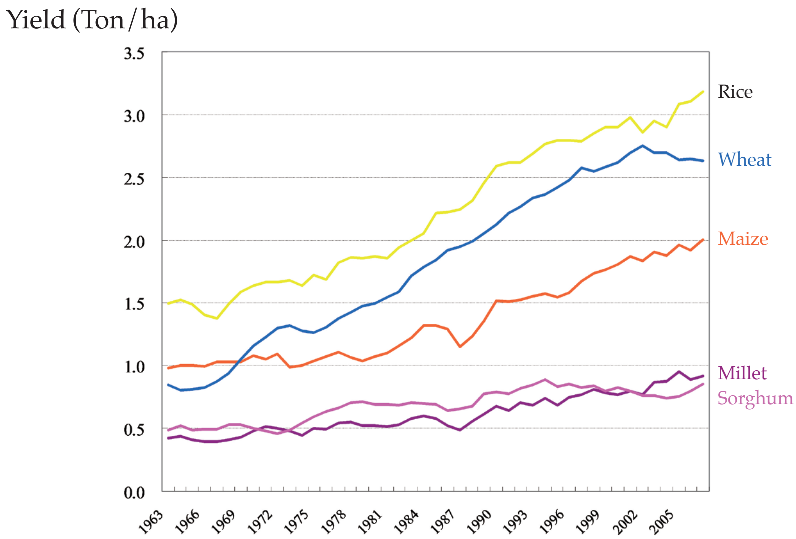
Table 4. Technology adoption, paddy yields, labor inputs, and factor share of labor in Northern Ghana

	No adoption	Partial adoption				Full adoption
		Modern inputs only[a]	Some modern inputs	Modern inputs, bunding, and leveling	Some modern inputs, bunding and leveling	
No. of households (%)	63 (11.6)	78 (14.3)	349 (64.0)	37 (6.8)	84 (15.4)	47 (8.6)
Yield (ton/ha)	1.46	1.70	1.95	1.98	2.33	2.59
Labor (days/ha)	102	152	187	204	238	264
Factor share of labor (%)	61.5	62.6	54.6	52.8	49.5	47.6

a. Modern inputs refer to the adoption of MVs and chemical fertilizer application.
b. Factor share of labor is the total cost of labor divided by the total value of production.

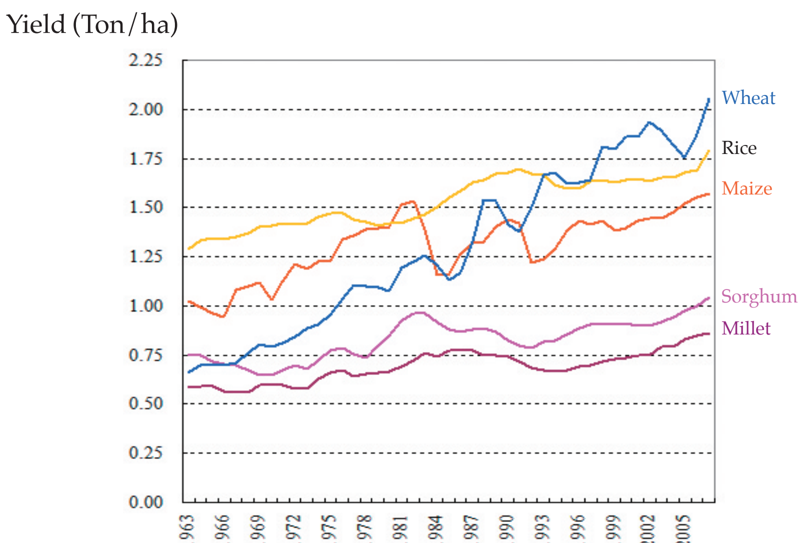
Figure 1. Grain yields in India and SSA, 3-year moving averages.

Figure 1a. India



Source: FAOSTAT

Figure 1b. SSA



Source: FAOSTAT

Figure 2. Adoption of new technologies before, during, and after the Lowland Rice Development Project (LRDP) in Northern Ghana.