Policy Note

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Toward a Rice Green Revolution in Sub-Saharan Africa

Keijiro Otsuka*, Yukichi Mano†, and Kazushi Takahashi‡

Abstract

The time is ripe to pursue a Green Revolution in rice in sub-Saharan Africa (SSA) as a means of promoting productivity growth, food security, and poverty reduction. This is partly because rice is an up-and-coming crop in this region and partly because we have now accumulated deep knowledge about rice cultivation in SSA. This policy note attempts to show what needs to be done to realize a rice Green Revolution in SSA, based on more than ten years of empirical inquiries into rice production by our research team in selected countries in the region. The primary strategy for achieving this goal is to strengthen the rice extension system to promote farming intensification along with the adoption of improved rice management practices. Complementary strategies comprise the diffusion of power tillers, the expansion of irrigated areas, and the quality improvement of milled rice using modern milling technologies.

* Kobe University, Institute of Developing Economies
† Hitotsubashi University
‡ National Graduate Institute for Policy Studies

This policy note is based on the research project, "An Empirical Analysis on Expanding Rice Production in Sub-Saharan Africa Phase 2," organized by the JICA Ogata Research Institute, which covers Mozambique, Tanzania, Uganda, Kenya, Ghana, Cote d'Ivoire, and Senegal. This policy note builds on an earlier one prepared by K. Otsuka, entitled "Evidence-Based Strategy for a Rice Green Revolution in Sub-Saharan Africa," JICA-RI Policy Note No. 5, 2019. This note has broader coverage in terms of topics, study periods, and locations, dealing not only with the impact of the rice cultivation training programs in both rainfed and irrigated areas in the short and long term but also with the impacts of mechanization, irrigation, and improved rice milling technology.

1. Introduction

It has been increasingly recognized that lowland rice is an up-and-coming crop in SSA. In their comprehensive review article on rice production in SSA, Balasubramanian et al. (2007) argue that the abundant supply of agro-climatically suitable wetland and water resources can support a significant expansion in rice area and productivity. An advantage of lowland rice relative to maize and other staple crops lies in the observation that a technological package to boost productivity is relatively well established and directly transferable from tropical Asia (Otsuka and Larson 2013).[1] This policy note argues that technologies used in the Asian rice Green Revolution – the intensive use of modern inputs such as improved rice varieties and inorganic fertilizer, combined with improved cultivation practices – can contribute to significant improvement in the productivity of rice farming in SSA.

Figure 1, which shows the average paddy yield in SSA and India, as well as the top five countries in SSA,[2] provides supportive evidence. The average yield in India was roughly 1.5 tons per hectare in the early 1960s, which is roughly the same as the average yield in SSA in the 1990s. Yield in India has been increasing since then, whereas yield in SSA gradually increased this century. This increasing yield trend in SSA may be attributed, at least in part, to the adoption of rice Green Revolution technologies in advanced areas, judging from the fact that the average yield of the top five countries began increasing sharply from around 1990 and approached the level achieved in India in the 2010s. There is no doubt that the rice Green Revolution has successfully taken hold in advanced areas in SSA.

What are the major constraints that prevent the full-fledged success of the rice Green Revolution in SSA? Policymakers and researchers have often assumed that the Green Revolution requires only the use of modern inputs, such as modern varieties (MV) and chemical fertilizers (Gollin et al. 2021; Carter, Laajaj, and Yang 2021), ignoring the role of improved cultivation practices, such as transplanting in rows, land leveling, and bunding (Abe and Wakatsuki 2011). Otsuka and Muraoka (2017) emphasize that Green Revolution technologies are management intensive in nature.

There is little doubt that a key to disseminating the management-intensive technologies is training by extension agents. Indeed, Otsuka and Larson (2016) show the results of down-to-earth case studies in Mozambique, Tanzania, Uganda, Ghana, and Senegal that demonstrate that lowland rice yield was enhanced significantly by training in rice cultivation practices in SSA. According to Takahashi, Muraoka, and Otsuka (2020), an efficient public-sector extension system holds the key to success in the rice Green Revolution in SSA.

In this policy note, after providing our conceptual framework in Section 2, we show evidence that rice cultivation training is a crucial entry point to achieving the rice Green Revolution in SSA in Section 3. We argue in Section 4 that other complementary improvements, such as agricultural mechanization, irrigation development, and efforts to improve the rice quality by adopting improved milling machines, are also crucial.

2. Conceptual Framework

The rice Green Revolution involves intensifying rice cultivation, i.e., the intensive use of modern inputs and application of improved cultivation practices.

Some improved cultivation practices, such as selection of good quality seeds, and pest and weed control, are also expected to enhance paddy quality. Although intensification usually means increased use of inputs, we would like to include appropriate harvesting, drying, and storing activities as components of the intensification process. Paddy yield and profitability of rice farming are enhanced by such intensification. While the application of modern inputs has been often emphasized, we should also realize that complementary cultivation practices have commonly been adopted in Asia. Figure 2 illustrates our conceptual framework, which explains how to achieve the rice Green Revolution through the intensification of rice farming.

We hypothesize that the core development strategy ought to be a rice cultivation training program. We can hardly expect a significant and sustainable improvement of rice productivity without improving cultivation practices, such as seed selection, bund construction, leveling, weeding, and proper timing and spacing of transplanting. Because these cultivation practices are knowledge intensive, training of farmers to acquire accurate management knowledge is necessary to realize the yield potential fully.

This emphasis on rice cultivation training does not imply that other factors, such as mechanization and irrigation, are unimportant. On the contrary, they play critical complementary roles in facilitating the intensification of rice cultivation. We postulate that mechanization, particularly the introduction of power-tillers, facilitates proper land preparation and induces the adoption of complementary cultivation practices. The use of tractors is also expected to lead to the extensification of rice farming, i.e., the expansion of cultivation area, owing to the efficiency of tractors in land preparation, including construction and plowing of new paddy fields. Irrigated areas tend to be more intensively cultivated and more productive than rainfed areas (Balasubramanian et al. 2007; David and Otsuka 1994). As the irrigated paddy area accounts for a minor fraction of the total paddy area in SSA, whether a rice cultivation training program effectively improves productivity in the rainfed area is a crucial question to be discussed below.

It is often argued that milled rice produced in SSA cannot compete with the high-quality rice imported from Asia. We believe that improved milling technology, especially removing stones and other impurities, combined with the grading of paddy and differential pricing of paddy based on the quality, is likely to stimulate the production of high-quality paddy (Kapalata and Sakurai 2020; Ogura, Awuni, and Sakurai 2020). Although we show merely descriptive evidence in what follows, it must be understood that the original studies cited here support our arguments with rigorous experimental methods and econometric analyses.

We do not prioritize input subsidy policies, particularly for fertilizer use, to realize the rice Green Revolution in SSA, even though such policies are popular among policymakers in this region. We need to emphasize that the use of fertilizer is not profitable unless improved cultivation practices are employed together with the adoption of fertilizer-responsive MVs. Indeed, Morris et al. (2007), based on an extensive literature review of fertilizer use in SSA, argue that the main cause of low fertilizer use in SSA is low profitability, and hence, the results of fertilizer subsidies are generally disappointing. More recently, Holden (2019) argues that input subsidy policies are not effective in increasing input use and productivity significantly in SSA. Based on these findings, as well as case studies of the impact of credit on input use and paddy yield in irrigated areas in Kenya (Njagi, Mano, and Otsuka 2016) and Tanzania (Nakano and Magezi 2020), we do not consider that unavailability of credit is a primary constraint on the rice Green Revolution. Rather, we consider that the adoption of improved cultivation practices is a prerequisite for the profitable use of chemical fertilizer.

3. Training as an Indispensable Entry Point

This section reviews the results of five new case studies, two of which are concerned with the short-run impacts of rice cultivation training in rainfed areas (Mozambique and Tanzania). The other three are concerned with longer-term impacts and the extent of information spillovers from participants to non-participants in training in rainfed (Uganda) and irrigated areas (Cote d'Ivoire and Tanzania).

Rice farming in Mozambique is undeveloped and rainfed, with direct seeding of local varieties without any fertilizer. Kajisa and Vu (2021) evaluated a randomized controlled trial (RCT) of rice cultivation training in the Central Region implemented by the Japan International Cooperation Agency (JICA). After the baseline survey was conducted in the 2016–17 season, rice cultivation training programs were offered to six farmer's associations in 2017 and another six associations in 2018, referred to as groups 1 and 2, respectively. According to Table 1, paddy yield was lowest among the control farmers (i.e., no assignment of training) in the post-training year of 2018–19, even though it was highest in the pre-training year of 2016–17. Since paddy yield depends on rainfall in the study sites as well as household and plot characteristics, it is challenging to identify the impact of rice cultivation training from the descriptive data. According to the regression analysis, which controls for relevant characteristics (not shown in this note), yield increased significantly by 450 to 550 kg per hectare among farmers in the treated groups compared with the control group.[3] This result is consistent with higher adoption of improved practices, such as plot leveling and straight-row transplanting among the treated groups than the control group (Table 1). Yield gain of 450 to 550 kg may appear modest, but this accounts for an approximately 30% improvement compared to the control group. This was achieved without applying any additional modern inputs, such as improved varieties or chemical fertilizer. These results are consistent with earlier studies of the impact of rice cultivation training on the rice production performance in rainfed areas in northern Ghana by deGraft-Johnson et al. (2014) and eastern Uganda by Kijima, Ito, and Otsuka (2012). Note also that rice farmers learn new cultivation practices from participating in the training program at the demonstration plot or from extension workers, whereas there is no clear evidence implying "social learning" or information spillover from participants to non-participants, at least in the short run in the Mozambique sites.

A spectacular example of high paddy yield triggered by training is found in the Kilombero Valley in Tanzania (Nakano, Tanaka, and Otsuka 2018). This area is favorable rainfed because additional water flows from nearby mountain ranges and the soil is fertile. Rice cultivation management training was offered by a large private rice plantation to nearby farmers in 2012 and 2013. The production management approach was called a "system of rice intensification (SRI)." However, unlike its original definition,[4] the use of MVs and chemical fertilizer were recommended, the use of irrigation was not assumed, and straight-row dibbling was promoted.[5] This is why Nakano, Tanaka, and Otsuka (2018) referred to the approach as a "modified SRI" or MSRI. As can be seen from Table 2, paddy yield was as high as 4.7 tons per hectare on plots where the trainees adopted MSRI technologies. This is higher than the highest paddy yield under rainfed conditions in tropical Asia to the best of our knowledge. There were no changes in technology adoption on other plots. Thus, the significant difference in paddy yield between MSRI plots and others can be attributed not only to the difference in the adoption of MVs and use of chemical fertilizer but also to the difference in cultivation practices. While substantial yield gains were observed, trained farmers did not adopt MSRI practices on all plots they had access to. The authors also did not find systematic evidence of informal spillover from the trained to non-trained farmers, even though their ongoing study anecdotally shows some signals of spillover.[6] Thus, how sustainable and widespread the impact of MSRI training will be is yet unclear in this study site.

According to Table 3, reported by Kijima (2018), the average yield of participants in the rice cultivation training in rainfed areas in Uganda increased by roughly 50% from 2008/09 to 2011/12. This high yield was maintained five to six years later, suggesting that the impact of rice cultivation training could be substantial and sustainable. In contrast, the average yield of non-participants did not increase as much as that of participants in 2011/12 but caught up in 2015/16. In this study site, however, participants in the training program were not randomly selected: participants were those who expressed interest in the training program, whereas non-participants did not show interest or were not informed about the training from village leaders. Thus, rigorous comparisons were made based on the propensity score-matching method between participants in training villages and farmers with similar characteristics in non-training villages, as well as between non-participants in training villages and farmers with similar characteristics in non-training villages. According to this analysis, while participants are found to improve yields and adopt transplanting in 2015/16 relative to their counterparts in non-training villages, there is no evidence that non-participants in the training villages improved their performance relative to farmers in non-training villages. The results thus do not provide supporting evidence on information spillovers from participants to non-participants in the training villages, even though this can be partly due to some unobserved heterogeneity between participants and non-participants.

More concrete evidence on the sustainability of training impacts and the spillover of technological knowledge is provided by the experimental study of irrigated areas in Cote d'Ivoire by Takahashi, Mano, and Otsuka (2019). Training participants and non-participants were randomly selected to avoid any imbalance in pre-training characteristics between them. Thus, there were no significant differences in paddy yield, fertilizer use, and the adoption rates of leveling and transplanting in the pre-training year of 2014 (see Table 4). When training was offered in 2015, participants and non-participants were initially requested not to communicate with one another in order to identify the pure impact of the training. It was revealed that the yield of participants, as well as their application of fertilizer and the adoption of leveling and transplanting in rows, significantly increased from 2014 to 2015 compared with non-participants. After the 2015 season, participants and non-participants were advised to communicate and spread the new practices. Consequently, the adoption rates of improved management practices of non-participants slightly increased from 2015 to 2016, indicating spillover effects.[7]

Longer-term impacts of rice cultivation training can also be confirmed by a study of the diffusion of improved rice production practices in irrigated areas in Tanzania (Nakano et al. 2018). In the training program, competent and motivated farmers, called key farmers, were selected and trained at nearby training institutes for 12 days before the main crop season in 2009. Each key farmer was requested to choose five intermediary farmers and train them in the improved rice production methods. Intermediary farmers were expected to train other ordinary farmers. As expected, key farmers' performance was better than intermediary and other farmers in 2008 before the training program (Table 5). The performance of only key farmers substantially improved after they took the training program in 2009, including an increased adoption rate of MVs. A critically important observation is that this high performance of key farmers was sustained for the next three years, indicating that the impact of the rice production training program is sustainable. Also noteworthy is that the performance of intermediary farmers improved gradually, followed by improved performance of other farmers. As shown in Figure 1, paddy yields of four to five tons per hectare are very high by any standard. Thus, there is no question that a rice Green Revolution occurred in irrigated areas in Tanzania due to the rice cultivation training program.

To sum up, the evidence reviewed in this section indicates that the impacts of cultivation training are significant and sustainable in both rainfed and irrigated areas, as well as being transmissible from participants to non-participants, especially in irrigated areas. It must be emphasized that such impacts were realized without any improvement in irrigation, marketing, or credit programs, among others. Thus, our findings can be taken to imply that rice cultivation training is a crucial entry point to the rice Green Revolution in SSA. Whether and to what extent new technology is disseminated from participants to non-participants in the training program in rainfed areas must be further analyzed. Such farmer-to-farmer information dissemination may be more difficult in rainfed areas than in irrigated areas, possibly because of the greater heterogeneity of agro-ecological farming conditions and the weaker social interaction among farmers in rainfed villages without a water user association.

4. Conceptual Framework

(4-1) Impacts of Tractorization

Power tillers were introduced in Asia in the 1980s to reduce the use of draught animals and labor (David and Otsuka 1994). However, SSA differs in this respect because manual labor has primarily been used for land preparation due to the unavailability of draught animals in most areas.

According to a study on the impact of the use of power tillers in Cote d'Ivoire by Mano, Takahashi, and Otsuka (2020), the average paddy yield is significantly higher for power-tiller users (4.7 tons/ha) than non-users (3.6 tons/ha). Furthermore, both family and hired labor were more intensively applied on plots plowed by power tillers. The use of power tillers also increased fertilizer application and enhanced the implementation of improved cultivation practices. Cultivation size is also significantly larger for power-tiller users (0.9 ha) than non-users (0.7 ha), indicating that the use of power tillers contributes to both intensification and extensification, as illustrated in Figure 2.

The case of Tanzania is unique not only because power tillers and hand hoes are used in land preparation but also four-wheel tractors and draught animals. While four-wheel tractors were most common in 2018, the use of power tillers has been increasing sharply. Several important observations can be made from Magezi, Nakano, and Sakurai (2021). First, the adoption of power tillers is associated with the highest yield, the highest adoption of bunds and straight-row transplanting, and the highest application of chemical fertilizer. Second, the adoption of both power tillers and four-wheel tractors is associated with a larger rice cultivation area per household. Third, there is no evidence that the use of four-wheel tractors contributes to intensification compared to the use of draught animals or hand hoes. Judging from this analysis, the introduction of power tillers seems to be quite conducive to both the intensification and extensification of rice farming in SSA.

(4-2) Impacts of Irrigation

There is no question that irrigation has significant impacts on the performance of rice farming because rice plants rely on water. According to Balasubramanian et al. (2007), the average paddy yield of 16 countries with less than a 10% irrigated ratio was 1.6 tons per hectare in 2004. By contrast, the average of four countries with more than a 90% irrigation ratio (i.e., Cameroon, Kenya, Mauritania, and Swaziland) was 3.9 tons per hectare in the same year. A similar tendency was found in tropical Asia in the late 1980s (David and Otsuka 1994).

One of the critical questions is whether the rate of return to investment in large-scale irrigation schemes is high enough to justify such investment. A recent study by Kikuchi et al. (2021) estimated the rate of return to irrigation investment in the Mwea Irrigation Scheme in Kenya by asking the hypothetical rate of return if the Mwea Irrigation Scheme were constructed as a new scheme now. The estimated internal rates of return are reasonably high (6.4% to 13.3%) if the value-added ratio of 0.8 is assumed, but lower than 8% if the value-added ratio of 0.5 is assumed.[8] Note that the Mwea Irrigation Scheme is considered to be one of the most successful irrigation schemes in SSA in view of its extremely high yield. The apparent conclusion is that the rate of return to investment for such a successful large-scale irrigation scheme as Mwea is not very high, mainly because world rice prices have remained low after the success of the Asian Green Revolution.[9]

We would like to make a couple of additional comments on the rate of return to investment in irrigation in SSA. First, rates of return would be higher if we assume that benefits of irrigation schemes are accrued not only to producers but also to various economic sectors, including input suppliers, rice milling and trading, and other related businesses through economic linkages and transactions. If such multiplier or market-wide "general-equilibrium" effects are taken into account, the net benefits for the entire economy could be enlarged to justify investment in irrigation. Second, irrigation projects, including the Mwea Irrigation Scheme, often provide training for farmers on rice cultivation as well as water management (Kikuchi et al. 2021). Because of the possible complementarity between improved cultivation practices and availability of irrigation, well-designed training on appropriate rice cultivation may significantly enhance the rate of return to large-scale irrigation investments.

(4-3) Role of Grading Paddy and Upgrading Milled Rice

The quality of milled rice depends on the quality of milling machines, particularly the use of destoners and color sorters, aside from proper timing of harvesting of paddy and its impeccable drying. Rice millers are in a good position to provide information about appropriate harvesting and drying to farmers and local traders and provide information about milled rice quality to urban traders and consumers through branding and marketing for supermarkets in both Asia (Reardon et al. 2014) and SSA (Ogura, Awuni, and Sakurai 2020).

Mano, Njagi, and Otsuka (2022) observe similar improvements in rice milling machines in the Mwea Irrigation Scheme in Kenya. As in many other places in SSA, a major factor impairing the quality of milled rice is the inclusion of small stones and other impurities. However, they can be removed by installing destoners. Three rice millers adopted destoners in 2011 and 34 millers by 2019.[10] The estimated market share of non-adopters was 80% in 2011 but decreased to less than 10% in 2019. Rice millers adopting destoners have a greater milling capacity, charge higher milling fees, and fetch 10% higher prices for milled rice sold than non-adopters. Furthermore, 50% of the early adopters and 25% of the late adopters had brand names as of 2019, and only these millers sold milled rice to urban supermarkets.

5. Concluding Remarks

We found that the impact of rice cultivation training programs is significant not only in the short run but is also long-lasting, and it is spreading through information spillovers, particularly in irrigated areas. Thus, we advocate for the rice cultivation training program as a critical entry point, even though we will have to inquire further into the existence and scale of spillover effects of the training program in rainfed areas. We found that using power tillers promotes the intensification of rice cultivation by thorough plowing and leveling and by inducing increased labor use for care-intensive activities. We found that the return to large-scale irrigation investment does not appear reasonably high unless market-wide "general-equilibrium benefits" are considered, triggered by irrigation investment, and accrued to closely related sectors of the economy. We also found evidence that the introduction of improved milling machines has a significant impact on the quality of milled rice.

In conclusion, we argue firstly that strengthening the public extension system for improved rice cultivation must be a central strategy to realize the rice Green Revolution in SSA. Secondly, we argue that the promotion of power-tillers must play a complementary role in supporting the rice Green Revolution. Thirdly, since the availability of irrigation water is a decisive factor affecting the performance of rice cultivation, the benefits and costs of large-scale irrigation projects in SSA should be carefully reconsidered. Finally, we recommend training rice millers in the use of improved rice milling machines to enhance the quality of African milled rice. There is little doubt that a full-fledged rice Green Revolution can take place in SSA if the rice extension system is adequately strengthened, power-tillers are widely diffused, irrigated areas expand significantly, and the quality of milled rice is improved.

[1] We advocate increases in the productivity of lowland rice cultivation, but not upland rice, such as NERICA, because of the absence of significant effects on productivity except in a few countries in SSA (e.g., Kijima, Otsuka, and Sserunkuuma 2011).

[2] India is chosen because its agro-climate is relatively similar to that of SSA, compared with other countries in Asia. The top five countries, in terms of the average paddy yield from 1961 to 2019, are Kenya, Niger, Senegal, Benin, and Mali.

[3] See original paper for further details.

[4] Original SRI principles include shallow and widely spaced transplanting of young seedlings, intermittent irrigation, and application of organic matter. The original SRI generally does not require additional purchased inputs, such as MVs or chemical fertilizer (Takahashi and Barrett 2014).

[5] Dibbling is a method of crop establishment wherein seeds are planted in holes prepared by simple tools, such as sticks.

[6] The authors reported that non-trained farmers started to adopt some recommended management practices five years after the training was provided. This result was presented in a research meeting held at the JICA Ogata Research Institute on February 24, 2022. However, the draft report has not yet been formally circulated, and further accumulation and evaluation of the evidence will be required.

[7] In a drought year of 2016, the yield of non-participants slightly exceeded that of participants.

[8] Since value added is defined as the value of production minus paid-out cost, it corresponds to income accrued to household-owned resources, such as family labor and land. Thus, if the ratio of value added to the value of production is high, a high proportion of the increased value of production becomes farmers' income, thereby leading to a high benefit from irrigation investment.

[9] Another potential reason raised by Kikuchi et al. (2021) is that, because the coverage and the number of beneficiaries in Mwea is relatively small among large-scale irrigation schemes, it cannot fully exploit scale economies, resulting in relatively high average construction costs.

[10] Note that most adopters of destoners also adopted pre-cleaners and graders, whereas some of them adopted color sorters, in contrast to non-adopters of destoners who did not adopt these devices

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Table 1: Changes in average paddy yield and selected technology adoption rates by training status in rainfed areas in Mozambique

	2016-17 Pre-training	2018-19 Post-training
1. Paddy yield (ton/ha):		
Training assigned, group 1	1.94	1.78
Training assigned, group 2	1.53	1.75
Training not assigned, control group	1.97	1.54
2. Plot leveling (%):		
Training assigned, group 1	14.1	66.7
Training assigned, group 2	18.6	45.5
Training not assigned, control group	24.4	3.8
3. Straight-row transplanting (%):		
Training assigned, group 1	1.3	46.2
Training assigned, group 2	0.0	35.6
Training not assigned, control group	0.0	0.0

The number of farmers is 78 in group 1 and 101 in group 2, whereas the number of farmers is 78 in the control group. The first group received the training in 2017, whereas the second group received it in 2018.

Source: Kajisa and Vu (2021).

Table 2: Average yield and technology adoption rates using the modified system of rice intensification (MSRI) training participation in rainfed areas in Tanzania in 2013

	Training villages					Non-training villages
	Trainees' MSRI plots		Trainees' non-MSRI plots		Non-trainees	
	2012 trainees	2013 trainees	2012 trainees	2013 trainees		
Paddy yield (tons/ha)	4.7	4.7	3.1	2.8	2.6	2.9
Chemical fertilizer use (kg/ha)	57.9	50.8	9.1	5.1	2.5	2.5
Share of MVs (%)	88.0	91.8	10.0	10.2	5.6	2.4
Share of straight-row dibbling (%)	80.0	77.6	0.0	0.0	0.0	0.8
Share of plots adopting recommended spacing (%)	60.0	55.3	0.0	0.0	1.6	2.4
No. of observations	25	85	20	59	126	83

Source: Nakano, Tanaka, and Otsuka (2018).

Table 3: Changes in average paddy yield and technology adoption rates by training status in rainfed areas in Uganda

	2008/09 Pre-training	2011/12 Post training (Short-term)	2015/16 Post-training (Long-term)
1. Paddy yield (ton/ha):			
Participants	1.24	1.95	2.07
Non-participants	1.35	1.58	2.03
2. Chemical fertilizer use (%)			
Participants	0.0	15.4	22.2
Non-participants	3.1	8.5	28.3
3. Bund construction (%)			
Participants	51.1	89.7	88.9
Non-participants	60.9	67.8	63.3
4. Transplanting (%)			
Participants	66.7	79.5	91.7
Non-participants	63.7	66.1	77.4

The number of participants is 45, 39, and 36 in respective years, whereas non-participants are 64, 59, and 53, respectively.

Source: Kijima (2018).

Table 4: Changes in average paddy yield and technology adoption rates by training status in irrigated areas in Cote d'Ivoire

	2014	2015	2016
1. Paddy yield (ton/ha)			
Participants	3.44	4.05	3.42
Non-participants	3.94	3.67	3.72
2. Fertilizer use (kg/ha)			
Participants	215	249	233
Non-participants	254	261	255
3. Leveling (%)			
Participants	77.2	85.7	86.7
Non-participants	79.1	67.7	81.0
4. Transplanting in row (%)			
Participants	5.4	37.8	34.9
Non-participants	1.9	10.8	17.9
Rainfall in July (mm)	29.9	92.5	19.8

Source: Takahashi, Mano, and Otsuka (2019)

Table 5: Changes in paddy yield and technology adoption by training status (key, intermediary, and other farmers) in irrigated areas in Tanzania

	2008	2009	2010	2011	2012
	Pre-training	During training		Post-training	
Key farmers					
Paddy yield (tons/ha)	3.07	4.40	4.81	5.34	4.67
Share of MVs (%)	46.2	69.2	75.0	54.4	66.7
Chemical fertilizer use (kg/ha)	63.4	115.8	137.7	178.3	131.3
Adoption rate of plot leveling (%)	46.1	76.9	81.3	86.7	76.9
Adoption rate of transplanting in rows (%)	23.1	76.9	93.8	93.3	92.3
No. of observations	13	13	16	15	13
Intermediary farmers					
Paddy yield (tons/ha)	2.47	2.57	2.84	4.63	3.93
Share of MVs (%)	30.4	44.4	54.8	34.4	49.5
Chemical fertilizer use (kg/ha)	22.2	49	79.1	103.9	95.2
Adoption rate of plot leveling (%)	43.5	70.4	74.2	79.2	62.5
Adoption rate of transplanting in rows (%)	13.0	44.4	64.5	45.8	58.3
No. of observations	23	27	31	24	31
Other farmers					
Paddy yield (tons/ha)	2.57	2.67	2.53	3.58	3.67
Share of MVs (%)	26.7	26.8	32.3	23.6	32.9
Chemical fertilizer use (kg/ha)	46.5	58.3	69.7	85.8	83.2
Adoption rate of plot leveling (%)	54.8	64.1	69	76.2	66.9
Adoption rate of transplanting in rows (%)	11.1	19.0	25.8	26.9	36.9
No. of observations	135	142	155	130	130
Annual rainfall (mm)	1027	869	917	1547	651

Source: Nakano et al. (2018).

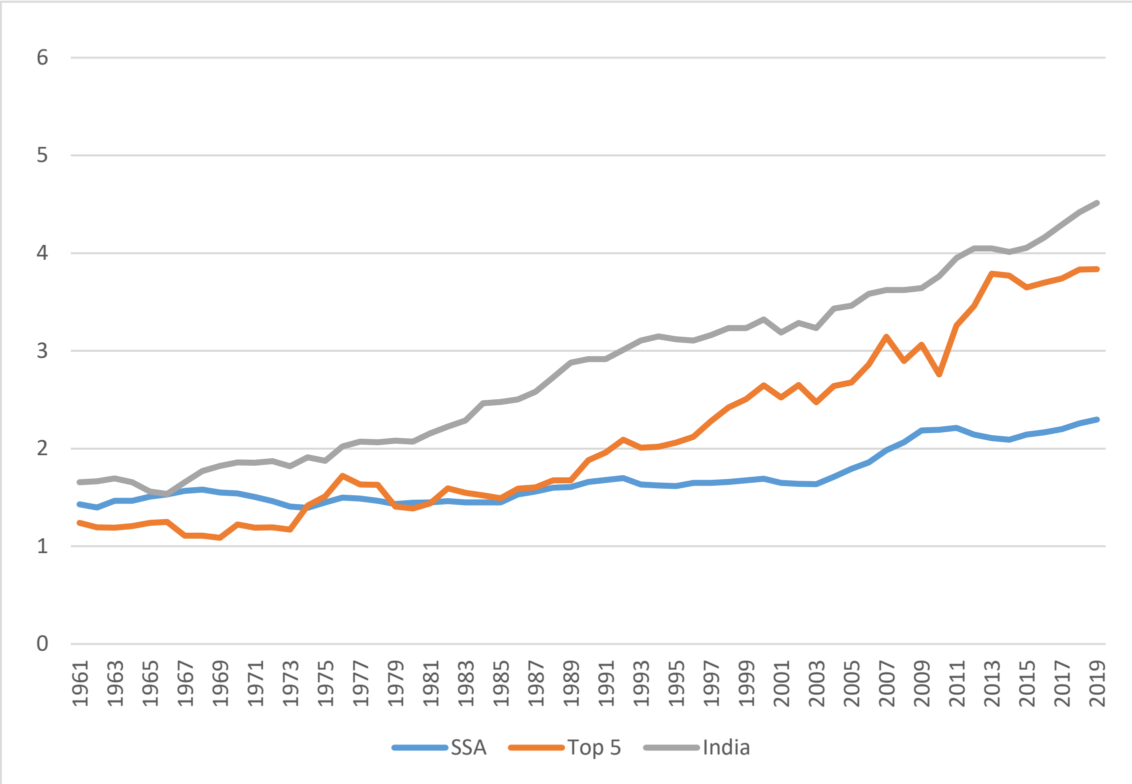

Figure 1: Changes in average paddy yield in SSA, top five countries,[a] and India (ton/ha), 3-year moving averages

(*Source*: United States Department of Agriculture 2021)

[a] Top five countries are Kenya, Niger, Senegal, Benin, and Mali.

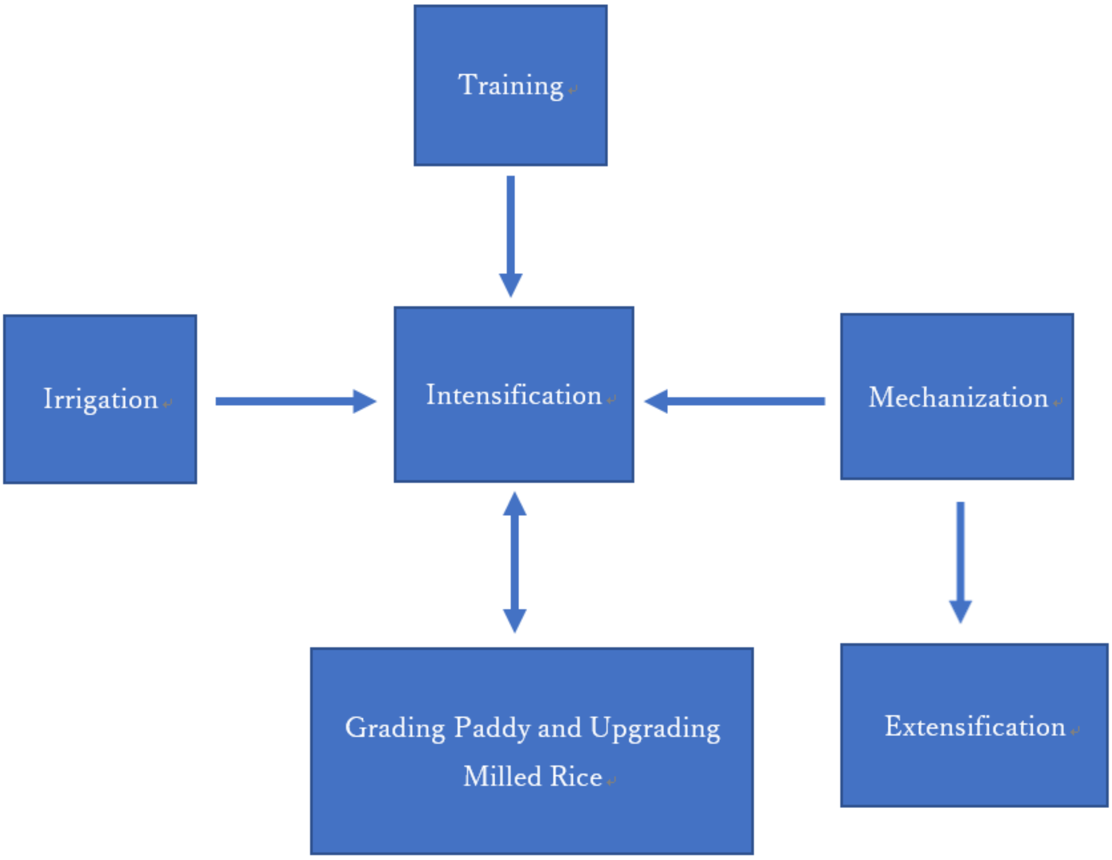

Figure 2: A conceptual framework to achieve a rice Green Revolution through intensification

Source: Authors.

Contact:
JICA Ogata Sadako Research Institute for Peace and Development
10-5 Ichigaya Honmura-cho Shinjuku-ku Tokyo 162-8433, JAPAN
TEL: +81-3-3269-2357 FAX: +81-3-3269-2054
URL: https://www.jica.go.jp/jica-ri/index.html